THE USE OF REMOTE SENSING DATA FOR BROAD ACRE GRAIN CROP MONITORING IN SOUTH-EAST AUSTRALIA

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DECLARATION

The work in this thesis is to the best of my knowledge and belief, original except where acknowledged in the text. The author hereby declares that the contents of this thesis have not been submitted, either in whole or in part, for a degree of any kind at this or any other academic institution.

Isabel Coppa

March 2006

DE USU RERUM EX LONGINQUO EMISSARUM UT AESTIMETUR QUALES SEGETES PER LATIFUNDIA PARTIUM AUSTRALIAE INTER MERIDIEM ET SOLIS ORTUM SPECTANTIUM SITA EVASURAE SINT

Deo gratias ago qui hanc mihi copiam in gradum Philosophiae Doctoris studendi contulerit et qui meae viae sic faverit. Sit Ei soli omnis gloria.
Spero ut haec studia rem rusticam hac, ut ita dicam, extraterrestria investigandi aetate promoveant, quibus usi agricolae segetibus pluribus ita frui possint ut orbi nostro non noceant et esurientes alamus.

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LIST OF ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ACRES	Australian Centre for Remote Sensing
ALMIS	Agricultural Land Management Information System
AML	Arc Macro Language
ASW	Available Soil Water
CD	Compact Disk
CNES	Centre National d'Etudes Spatials
CNN	Cereal Cyst Nematode
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DLR	German Aerospace Centre
DN	Digital Number
DNRE	Department of Natural Resources & Environment
DSS	Decision Support System
DVI	Difference Vegetation Index
EM	Electromagnetic Spectrum
ERS	Earth Resource Satellite
ESA	European Space Agency
ESRI	Environmental Systems Research Institute
ERDAS	Earth Resources Data Analysis System
FAO	Food & Agricultural Organization
GCP	Ground Control Point
GIS	Geographic Information System
GPS	Global Positioning System
GRDC	Grains Research and Development Corporation
HRG	High Resolution Geometric Imaging System
HRV	High Resolution Visible Imaging System
HRVIR	High Resolution Visible and Infrared Sensor
ID	Identification Number

IFOV	Instantaneous Field Of View
IR	Infra Red
IRS	Indian Remote Sensing Satellite
LAI	Leaf Area Index
MIR	Mid Infrared
MODIS	Moderate Resolution Imaging Spectroradiometer
N	Nitrogen
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
NRS	Natural Resource Systems
PAN	Panchromatic Sensor
PAR	Photosynthetically Active Radiation
QA	Quality Assurance
R	Red part of the Electromagnetic Spectrum
RMIT	Royal Melbourne Institute of Technology
RMS	Root Mean Square
RVI	Ratio Vegetation Index
SAMZ	Satellite-Derived Management Zones
SAVI	Solid Adjusted Vegetation Index
SPOT	Satellite Pour l'Observation de la Terre
TIR	Thermal Infra Red
TIROS	Television Infrared Observation Satellite
TM	Thematic Mapper
TVI	Triangular Vegetation Index
UMAC	Upper Midwest Aerospace Consortium
UTM	Universal Transverse Mercator grid system
VI	Vegetation Index
VIS	Visible range of the Electromagnetic Spectrum
VRT	Variable Rate Technology
VVF	Victorian Farmers Federation
WGS	World Geodetic System

ABSTRACT

In 2025, there will be almost 8 billion people to feed as the worlds population rapidly increases. To meet domestic and export demands, Australian grain productivity needs to approximately triple in the next 20 years, and this production needs to occur in an environmentally sustainable manner. The advent of Hi-tech Precision Farming in Australia has shown promise in recent time to optimize the use of resources. Most "precision farmers" produce yield maps at harvest. However when yield maps become available it is usually too late to apply management techniques that would address problems in the crop specific to the current season.

This study was motivated by the conviction of the author that in the future farmers in developed nations will consult remote sensing imagery of their paddocks in management decision making processes with the same certainty as they observe weather forecasts today. Since there was no operational satellite-based broad-acre crop monitoring system available in south east Australia before the start of the research, the aim was to design a prototype concept for a system that used commercially available satellite imagery to monitor the crop development throughout the crop season. The system was named ALMIS (Agricultural Land Management Information System) and tested with 25 farmers in the Gooroc area in Victoria with a focus on the following crop types; barley, canola, chickpeas, lentils and wheat. Through the study, several components providing vital information for a crop monitoring system were developed from satellite imagery, including crop type discrimination, quantitative crop parameters, crop yield estimates. Furthermore, critical parameters for the system were determined.

This thesis aims to develop a concept for an operational crop monitoring system by answering the following research questions:

Using SPOT Satellite Imagery:

- What are the “typical” spectral properties of crops in the south east Australian cropping region? Can crop types be distinguished? What accuracy of identification can be obtained and when during the growth of the crop?

- Can the crop-parameters “plant height”, “above-ground green biomass”, “dried green biomass” and “plant water”, plus soil moisture parameters be estimated in the south east Australian cropping region?

- Can crop yield be estimated prior to harvest?

- Can remote sensing contribute information for precision farming? How should an operational system be designed? What critical parameters need to be considered?

As crop parameter and yield estimates are crop type specific, it is important to have accurate crop type data. Therefore crop type classification using satellite data for the most commonly cultivated grain crops in South East Australia was investigated. Typical spectral signatures as seen by the commercial SPOT satellite were extracted from the imagery for the five crop types under investigation at various phenological development stages throughout the crop season. This database enabled crop type classification far superior to the average results reported by the literature review. However, temporal shifts caused by seasonal meteorological patterns were observed in the remote sensing data of 1998 and 2001; this has implications when translating classification models from one year to the next strongly suggesting that models with a-priory knowledge of climatic data or sowing dates need to be developed in future studies.

Quantitative plant parameter such as biomass, water content and crop height enable the farmers to apply the appropriate amount of fertilizers and chemicals to areas in the field where they are required. Furthermore land managers are alerted to areas that perform outside the expected crop development, can monitor quantitive response to management decision (such as urea application) and can schedule harvest operations.

In the study samples were collected in the field and statistically related to the remote sensing data. When estimating crop parameters from crops other than chickpeas, simple linear regression models yielded only moderate results; it was anticipated that crop parameters could be predicted with more complex modelling approaches as the crop parameters followed a parabolic path, similar to the path of their respective vegetation index, as their phenological development progressed. Linear models were developed for chickpeas with R^2 results between 0.8 and 0.91 for the various plant parameters.

Farmers would like to have a yield map early in the season to optimize their returns (minimum financial input for maximum financial output). Knowing reliable yield targets will also enable the farmer to maintain soil nutrient supply at appropriate levels- ensuring sufficient supply without surplus leaching into ground water tables. In the study, yield maps were related to the remote sensing data and various models were developed. Best results were achieved for canola (R^2=0.88), but the other crop types also showed promise. Crop yields in 1998 were affected by severe frosts. It is therefore necessary to test the models on data of seasons not affected by frosts, to ensure their accuracies.

Often farmers climb on the roof of the tractor to get a bird's eye view of part of the paddocks, in order to pick up abnormalities in crop development due to insects, pests, diseases etc. The analysed satellite imagery assisted farmers in targeted scout walks. Problems related to frost, insects, diseases, weeds, historic management decisions, equipment failure, etc. were recorded. The capability of SPOT remote sensing data to detect problem areas in broad area grain fields is most valuable for precision farming applications to optimize variable rate technology applications and to delineate crop management zones.

It is essential to draw on the feedback of farmers, the end users, in the product development of a crop monitoring system. The feedback given by the Gooroc farmers, together with the results gained from the ALMIS field studies and considerations reported in the literature were the foundations for the concept design proposal. As critical parameters were identified (amongst others): delivery of data within 1-2 days after acquisition; data should have spatial resolution better than 10 meters, and appropriate geometric and radiometric stability; in an easy-to-use computer interface (software or via internet), carefully timed image data should be offered as near infrared imagery, colour-coded vegetation index, percentile rating for each paddock, quantitative vegetation parameter and yield forecast maps; assistance should to be given to farmers by trained agronomists to convert information into management decisions, and training courses are needed to give end users basic understanding of the technologies utilized by such a system; consolidated strategic development efforts need to be employed to further the use of the information in decision support systems and variable rate technology. As the technology is in it's infancy it needs to be supported by government and industry initiatives to reach critical mass.

It was concluded that information from satellite remote sensing is greatly beneficial to the farming community of south east Australia, resulting in substantial economic benefits for local farmers as it becomes widely adapted. The technology developed in this thesis contributes to the Australian goal of increasing crop yields in a profitable and environmentally friendly manner.

1. General Introduction

1.1 Introduction

This thesis investigates the use of remote sensing data for broad acre grain crop monitoring in south east Australia. In this chapter the relevance of the topic is presented in the context of global development forecasts for the next twenty years. Australian grain productivity needs to approximately triple by 2025, and production needs to occur in an environmentally sustainable manner (GRDC, 2004). The concept of a crop monitoring system developed in this study will contribute towards these goals. The aim and scope of the thesis are presented as well as the thesis layout.

1.2 Global developments in agriculture

In 2025, there will be almost 8 billion people to feed, as the world population continues to rapidly increasing (United Nations, 2001). Since Thomas Malthus wrote his "Essay on the Principle of Population as It Affects the Future Improvement of Society" in 1798 (Malthus, 1798), a debate has focused on the perceived race between supply (seen to grow linearly) and population (seen to grow exponentially). New lands, new technology, and capital investment in irrigation have delayed the "Malthusian cross" (i.e. when population growth rate exceed the rate of food supply increases) for most of the world in the past. The challenge world agriculture is facing in the next twenty years is enormous. World food production has to more than double (McCalla, 1994; Dyson, 1999).

Until the middle of the twentieth century, expansion of cultivated area roughly kept pace with population growth. In the last fifty years, the doubling of cereal output came from three sources (McCalla, 1994):

- expansion of the area under cultivation
- increased intensity of land use (mainly through expanded irrigation)

- crop yield increases.

The availability of suitable crop land for new cultivation is limited and, as a consequence, the expansion of cereal crop lands has slowed substantially since 1980 (Rosegrant et al. 2002). Globally, 69 % of all cereal area is non-irrigated, including 40 % of rice, 66 % of wheat, 82 % of maize and 86 % of other coarse grains (Rosegrant et al. 2002). Worldwide, non-irrigated cereal yield is about 2.2 metric tons per hectare, which is about 65 % of the irrigated yield (3.5 metric tons per hectare) (Rosegrant et al. 2002). Non-irrigated areas currently account for 58 % of world cereal production (Rosegrant et al. 2002). Rosegrant et al (2002) modelled baseline projections and reported that dryland agriculture will continue to play a major role in cereal production, accounting for about one-half of the increase in global cereal production between 1995 and 2021-25. The importance of non-irrigated cereal production is partly due to the dominance of dryland agriculture in developed countries. More than 80 % of cereal area in developed countries is non-irrigated, much of which is highly productive maize and wheat land such as that in the Midwestern United States of America and parts of Europe (Rosegrant et al. 2002). The average non-irrigated cereal yield in developed countries was 3.2 metric tons per hectare in 1995, virtually as high as irrigated cereal yields in developing countries. Non-irrigated cereal yields in developed countries are projected to grow to 3.9 metric tons per hectare by 2021-25 (Rosegrant et al. 2002).

The area of irrigated lands used for cereal production has more than doubled between 1950 and 1980. Most of this increase can be attributed to a legacy of the large scale diversion of river water to supply (low efficiency) canal irrigation projects developed during the 1950–1970 period (Lambert et al. 2002). Irrigation enables production of two or more crops per year on the same piece of land, thus increasing the intensity of land use (Cassman, 1999). However, the rate of increase of irrigated land has slowed considerably since 1980 because of rising costs and the threat of long-term salinization (McCalla, 1994). This form of irrigation-induced salinization, also known as secondary salinization, has been extensively described and researched (for an overview, see Ghasemi et al. 1995). This salinization is, however, generally restricted to irrigation in the (semi) arid zone. Out of the 270 million ha of irrigated land in the world, about 110 million ha (roughly 40%) is located in this zone. No reliable global assessments are available, but indications are that waterlogging and secondary land salinization seriously affect the productivity of at least some 20–30 million ha which is about 25% of the irrigated area in the (semi) arid zone (Lambert et al. 2002).

Therefore, the current view is that the next doubling of food production must come primarily from increased productivity (i.e. yield) (McCalla, 1994). Feder and Keck (1994) argued that every 0.1 % of yield increase in the period 2010 to 2025 ‘substitutes’ for about 25 million hectares of rainfed cropland. While yields of some cereals, such as wheat and rice, have doubled in the last 40 years, yields of most other developing country crops-such as maize, cassava, sorghum, millet, beans, and edible legumes- have shown less rapid increases. Doubling the yields of wheat, rice and other basic food products will be problematic without increased research and development efforts (McCalla, 1994).

The yield per unit land has increased markedly in the last 40 years as a result of intensified crop management involving improved germplasm (biotechnology), greater inputs of fertilizer (Cassman, 1999) and the recent advent of precision agriculture management practices (Stafford, 2000).

New crops and improved seeds are being developed. The grain yield of cereals almost doubled last century as a result of conventional plant breeding (Richards, 2000). Molecular genetic biotechnology holds the promise of significant genetic improvements, but that promise is becoming reality much more slowly than earlier forecasts suggested (McCalla, 1994). Sinclair et al. (2004) noted that in spite of the optimistic predictions often made for transformations leading to plant genetic trait improvement resulting in increased yield potential, a historical perspective indicates that a much more moderate expectation is warranted. Forty years of research on the biochemistry and physiology of plant traits considered crucial for yield increases have resulted in few examples where such research led directly to a yield increase. Although past research has greatly increased the understanding of the factors associated with crop yields and contributed significantly to the development of molecular genetics, overall there are virtually no examples of such research leading directly to crop yield increase (Sinclair et al. 2004). As Miflin (2000) noted, an inability in past years to apply discoveries in plant biochemistry and physiology to practical challenges of crop improvement should engender caution concerning the short-term contribution that molecular genetic research might make to increasing crop yields.

Dyson (1999) suggested that it is inescapable that humanity will depend even more on synthetic nitrogen fertilizers for its food supply. In 1908 Fritz Haber combined nitrogen from the air with hydrogen from gas to synthesize ammonia (NH_4-N), and in 1914 Karl Bosch completed the first large synthetic fertilizers manufacturing plant (Frink, 1999). By the middle of the last century the new technology lowered the price of N fertilizer enough that farmers began applying near 100 kg/ha and raising yields in step (Frink, 1999). Using Gilland's equations (1993), Dyson (1999) estimated that there may have to be an approximate doubling of the global use of synthetic nitrogen to produce 3 billion tons of grain.

The difficult challenge facing world agriculture today is to double production on the same land base while maintaining or, hopefully, improving the natural resource base (McCalla, 1994). These are the twin challenges of creating environmentally-sustainable production systems, productivity improvement and improved management of natural resources (McCalla, 1994). Precision agriculture, as a crop management concept, can help address much of the increasing environmental, economic, market and public pressures on arable agriculture (Stafford, 2000).

Precision agriculture has generated a high profile in the agricultural industry over the last decade of the second millennium, although the fact of “within-field spatial variability” has been known for centuries. With the advent of the satellite-based Global Positioning System, farmers gained the potential to take account of spatial variability across their fields. The initiative has been technology-driven and many of the engineering developments are in place, but understanding of the biological processes on a localized scale is lagging behind. Nonetheless, further technology development is required, particularly in the area of sensing and mapping systems to provide spatially related data on crop, soil and environmental factors (Stafford, 2000). Precision agriculture is information-intense and could not be realized without the enormous advances in networking and computer processing power, and access thereof to farmers and farm mangers. Stafford (2000) estimated that by the end of the decade, most arable enterprises in the developed nations will have taken on the concept on a whole-farm basis.

1.3 Challenges for agriculture and regional land management in Australia

A doubling of global food demand may see the grain consumption of wheat, rice, and maize increase from 1.9 billion metric tons to 3.8 billion metric tons (McCalla, 1994). If developing countries are to grow their own food, and if population increases at 2 per cent per year, then their food production must rise by 2 per cent per year (McCalla, 1994). Carruthers (1993) argued that the tropics are incapable of producing enough basic foodstuffs for burgeoning cities in the developing world where the human population is estimated to be 4 billion by 2025. Indeed, heavily exploited tropical and subtropical environments may be lucky to support the remaining 50 % that still subsist from the land. Most likely, the world's developing regions are going to increasingly depend on cereal imports, both in absolute terms and as a proportion of their total consumption. Given this, the volume of world trade in cereals is expected to rise, and may more than double between 1990 and 2025. The trend has already started. The USA, Canada, and Australia continue as the main source of cereals for world markets, but increasingly they are joined in a subsidiary role by Europe and the former Soviet Union (Dyson, 1999). The developed countries export food to developing countries and increasingly import labour intensive manufactured goods (McCalla, 1994).

At present, the total domestic demand for grain in Australia (for food, stockfeed and non-food uses) is around 14 million tonnes of cereals, 1 million tonnes of pulses and 1.5 million tonnes of oilseeds (GRDC 2004). The domestic demand is expected to increase to 30–40 million tonnes of cereals, 1–2 million tonnes of pulses, and 1–2 million tonnes of oilseeds in 2025. This is due to increased demand as the Australian population increases and value adding (eg. production for export of tinned Falafels rather than export of unprocessed chickpeas) by new onshore food processing industries (GRDC 2004).

Predictions of export demand (assuming 25 % of previously exported grain will be used locally for domestic ingredients including stockfeed) range from a potential of between 60 million to 70 million tonnes of cereals by 2025. An additional 6 million and 7 million tonnes of pulses and around 6 million tonnes of oilseeds will be required (GRDC 2004). Overall, there is potential demand for Australian grain in the range of approximately three times the current demand by 2025 (GRDC 2004).

In the “SINGLE VISION for the Australian Grains Industry 2005-2025” strategic plan, the Grains Research & Development Corporation and Grains Council of Australia recognized that management of the environment and natural resource base is a major concern to producers that is seen as one of the key drivers of farm profitability. Good farming practice and good environmental stewardship are complementary and a key to prosperity. Hence one of the identified major goals is avoiding damage to the natural environment, particularly to the natural resources of soil, water, land, air and biota and ensuring the long term productivity, sustainability and resilience of natural systems (GRDC 2004).

1.4 Aims and scope of thesis

Today, advances in technology, have set the scene to make a near real-time satellite crop monitoring system a potential reality. Data reception, processing and delivery from commercial satellites can be achieved within hours (ACRES 2005; Raytheon 2005). The use of IT technology in rural areas has significantly increased in the last few years and is expected to continue. Of the 132,983 Australian farms with an estimated value of agriculture earnings of $5,000 or more, an estimated 54% used a computer and 46% used the Internet as part of their business operations for the year ended 30 June 2003 (ABS, 2004). This is a significant increase from 1998, when 44.8% of farms used computers and only 11.8% had internet access (ABS, 1999).

The author believes that in the future farmers in developed nations will consult remote sensing imagery of their paddocks with the same certainty as they observe weather forecasts today. Since there was no operational satellite based broad-acre crop monitoring system available in south-east Australia before the start of this research, the aim was to design a concept for a system that could assist farmers and land managers to better manage their crops.

After a cost- benefit analysis in 1997 the author commenced research at the then Victorian Department of Natural Resources and Environment to develop an operational crop monitoring prototype system, using conventional, available satellite imagery. A research strategy was developed and included amongst other tasks: finding a suitable test site, contacts to local farmers in the area, finding support from satellite companies, developing a prototype using suitable software and data for the crop monitoring system in addition to designing image analysis processes and distribution models. In the 1998 crop season, a trial of the early phase prototype crop monitoring system (called ALMIS) was tested with 25 farmers in the Gooroc area of Victoria, Australia and extensive field observations were conducted. ALMIS is short for Agricultural Land Management Information System. Several satellite companies supported the project, contributing imagery throughout the season. In 1999, the research was developed further at RMIT University and documented in this PhD thesis.

The scope of this thesis is to describe research on SPOT remote sensing data of the five agricultural crop types: barley, canola, chickpeas, lentils and wheat throughout the 1998 crop growth cycle in the Gooroc area. The findings were then integrated in the design of a concept for an operational crop monitoring system.

Research Questions

This thesis aims to develop a concept for an operational crop monitoring system by answering the following research questions:

Using SPOT Satellite Imagery:

- What are the "typical" spectral properties of crops in the south east Australian cropping region? Can crop types be distinguished? What accuracy of identification can be obtained and when during the growth of the crop?

- Can the crop-parameters "plant height", "above-ground green biomass", "dried green biomass" and "plant water", plus soil moisture parameters be estimated in the south east Australian cropping region?

- Can crop yield be estimated prior to harvest?

- Can remote sensing contribute information for precision farming? How should an operational system be designed? What critical parameters need to be considered?

1.5 Thesis layout

The thesis starts with an introductory chapter, acquainting the reader to the relevance of the topic to be investigated in this study. Chapter two reviews remotes sensing developments that can assist in the development of a crop monitoring system, the geospatial technologies and needs of precision agriculture, the status of crop monitoring systems using remote sensing, and the issues and challenges for satellite crop monitoring systems. In the third Chapter background information is given for the ALMIS case study. This includes a description of the ALMIS concept and the study area, the grains industry in Victoria and the crops under investigation.

Chapter four deals with the research design and methods. The conceptual design is introduced to the reader. Data sources, acquisition dates, data calibration and processing are discussed. In Chapter five the “typical” spectral properties as seen in the SPOT data of the five crop types are presented for the 1998 season and compared to signatures from 2001. Crop type classification using discriminant function analysis is discussed and results are presented. The correlation between the satellite data and plant-parameters, such as crop height, green biomass and dried green biomass, plant water and soil moisture are discussed in Chapter six. In Chapter seven, the correlations of precision farming yield data and the SPOT satellite data are investigated.

Chapter eight describes the project ALMIS that developed an early phase prototype crop monitoring system. ALMIS was trialled with 25 farmers in the test site. Examples of findings in the satellite data are presented. Chapter nine reports feedback from the farmers regarding the ALMIS prototype crop monitoring system and critical parameters for an improved version of a crop monitoring system are discussed. In Chapter ten results are discussed, future research areas are recommended and conclusions are drawn.

2. Remote Sensing applications in Precision Farming

2.1 Introduction

Different aspects that are relevant to the use of remote sensing in agriculture, in particular Precision Farming applications, are assessed in this chapter. Examples are drawn from the literature and a brief review of recently emerged crop monitoring systems is presented. Issues and challenges for such systems are discussed.

Throughout history, humans have created tools to multiply their efforts and overcome weaknesses. In the recent advent of the information age, tools in the area of the geospatial sciences and remote sensing have been created to overcome the following human weaknesses (Paris, 1998):

- Humans do not have an objective view of spatial information and cannot easily see the “big picture”
- Humans tend to forget details about previously seen spatial information. Old information lacks clarity and detail and hence it is difficult to see trends or changes over time
- Humans do not know their absolute location except in relationship to known landmarks
- Humans can only see objects in the visible spectrum (400 to 700 nm) neglecting important information in the UV, NIR, MIR, TIR, and microwave region of the EM.
- Humans cannot easily perceive information at different scales. Both the microscopic and the macroscopic are not perceived naturally, microscopes and macroscopes (eg. GIS) are needed.

To compensate for these limitations, technical developments have been made, such as GIS for storage and analysis of spatial information, Remote Sensing platforms that operate in the VIS, NIR, MIR, TIR and microwave region of the Electromagnetic Spectrum (EM) and GPS technology for absolute orientation in space. These technical developments have created new management opportunities in agriculture.

2.2 Evolution of Remote Sensing technologies and their application to agriculture

2.2.1 Definition of Remote Sensing

Lillesand and Kiefer (2000) defined Remote Sensing as the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation.

2.2.2 History of Remote Sensing

The technology of modern Remote Sensing began with the invention of the camera more than 150 years ago (NASA, 2005a). Although the first, rather primitive photographs were taken as "stills" on the ground, the idea and practice of looking down at the Earth's surface emerged when pictures were taken from cameras secured to tethered balloons for purposes of topographic mapping. The first known balloon photograph was taken in 1859 by Gaspard Felix Tournachon (later known as “Nadar”) of the French village of Petit Becetre near Paris (Simonett, 1983). By the first World War, cameras mounted on airplanes provided aerial views of fairly large surface areas that proved invaluable in military reconnaissance. From then until the early 1960s, the aerial photograph remained the single standard tool for depicting the surface from a vertical or oblique perspective. Satellite Remote Sensing can be traced to the early days of the space age (both Russian and American programs) and actually began as a dual approach to imaging surfaces using several types of sensors from spacecraft

(NASA, 2005a). The term "Remote Sensing," was first used in the United States in the 1950s by Ms. Evelyn Pruitt of the U.S. Office of Naval Research (NASA, 2005a). The development of meteorological satellites provided the impetus for most modern Remote Sensing. TIROS-1 was launched in 1960 and returned the first coarse views of cloud patterns. In 1972 NASA began the Landsat series with the launch of the Earth Resources Technology Satellite 1, which was later renamed Landsat 1 (NASA, 2005a), and since then has been followed by many other imaging satellites.

2.2.3 Sensor specifications

Satellite sensors collect the energy of the electromagnetic spectrum (Figure 2.1); the electromagnetic spectrum is the entire range of radiant energies or wave frequencies of solar radiation from the longest to the shortest wavelengths; it is divided into seven sections: radio, microwave, infrared, visible, ultraviolet, x-ray, and gamma-ray radiation (NASA, 2005b).

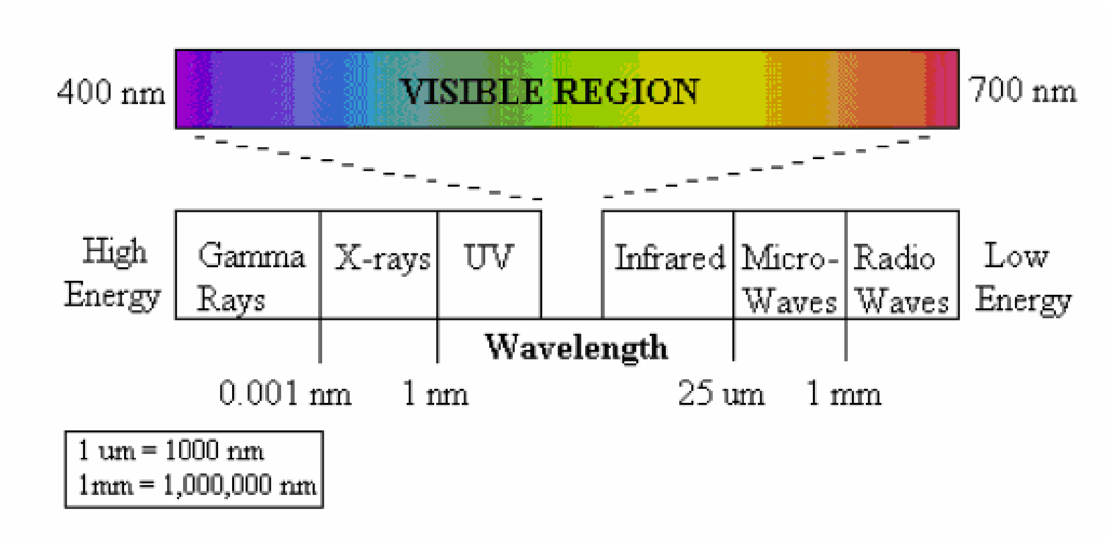


Figure 2.1: The electromagnetic spectrum (from Kyllo, 2003)

Remote Sensing instruments are characterized by their given resolutions; these include spectral resolution, radiometric resolution, spatial resolution and temporal resolution. The spectral resolution of a Remote Sensing instrument (sensor) is determined by the band-widths of the electromagnetic radiation of the channels used. High spectral resolution is achieved by narrow bandwidth widths which collectively are likely to provide a more accurate spectral signature for discrete objects than broad bandwidth. Radiometric resolution of a sensor is determined by the number of discrete levels into which signals may be divided. The spatial resolution describes the geometric properties of the imaging system; it is usually described as the instantaneous field of view (IFOV). The IFOV is defined as the maximum angle of view in which a sensor can effectively detect electromagnetic energy. The IFOV of satellites translate into a monitored pixel size on the ground. Temporal resolution is related of the repetitive coverage of the ground by the remote-sensing system.

As a discussion of all current satellites and their sensor specific specifications is beyond the scope of this thesis, the reader is referred to ERSC (2005). A list of current Earth Observation Satellites is published online by the Environmental Remote Sensing Centre. The following details are given for the satellite relevant to this study.

2.2.4 SPOT satellite

SPOT (Satellite Pour l'Observation de la Terre) is a joint venture between French, Swedish and German organizations and operated by the French-based company in Toulouse, SPOT Image. The first SPOT satellite, SPOT 1, was launched in February 1986 by the French Government Agency, Centre National d'Etudes Spatials (CNES). These were followed by SPOT 2, 3, 4 (Figure 2.2) and 5 (ACRES, 2003).

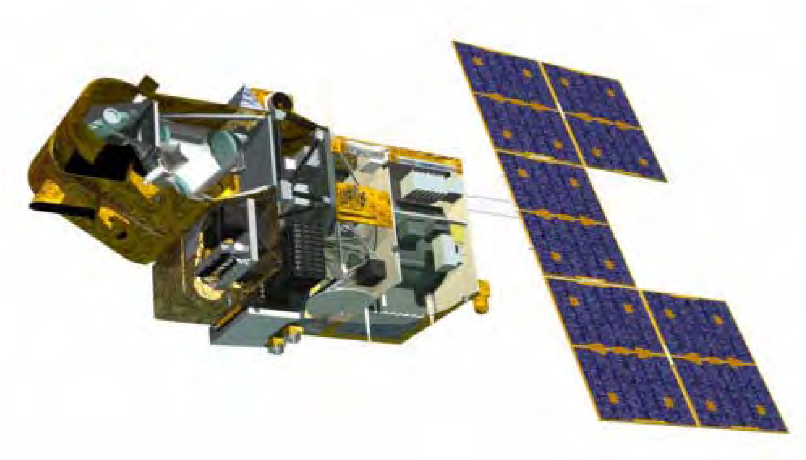


Figure 2.2: SPOT 4 satellite (from SPOT, 2003)

Table 2.1: Overview of launch dates and operational status of SPOT satellites

Satellite	Launch Date	Notes
SPOT 1	22 February 1986	Operational
SPOT 2	22 January 1990	Operational
SPOT 3	26 September 1993	Failed November 1996
SPOT 4	24 March 1998	Operational
SPOT 5	04 May 2002	Operational

The SPOT sensors have the ability to image from vertical viewing (nadir) up to plus or minus 27 degrees off-nadir. Satellite ground control can steer a plane mirror to achieve the off-nadir viewing capabilities. It is therefore possible for the sensors to image any point within a strip 475 km to either side of the satellite ground track. The satellite has 2 sensors, and when used in dual mode, both sensing instruments can be pointed to cover adjacent ground areas, while viewing the earth from the vertical (nadir) position. In this configuration the total swath width is 117 km with a 3km overlap common to both sensors (SPOT, 2003). If the satellite instruments had only vertical viewing capability, the revisit frequency would be 26 days. However, due to the SPOT sensors' off-nadir imaging ability the opportunity for revisiting the same area of the earth's surface is increased. During the 26 day repeat cycle of the SPOT satellite various passes over a specific area can be acquired with different viewing angles (SPOT, 2003). Table 2.2 gives a technical overview of the SPOT 1-5 satellites (SPOT, 2003).

Table 2.2: Technical summary of SPOT 1-5 satellites

	SPOT 5	SPOT 4	SPOT 1, 2 and 3
Instruments	2 HRGs	2 HRVIRs	2 HRVs
Spectral bands and resolution	2 panchromatic (5 m), combined to generate a 2.5-metre product 3 multispectral (10 m) 1 short-wave infrared (20 m)	1 monochromatic (10 m) 3 multispectral (20 m) 1 short-wave infrared (20 m)	1 panchromatic (10 m) 3 multispectral (20 m)

Spectral range	P: 0.48 - 0.71 µm B1: 0.50 - 0.59 µm B2: 0.61 - 0.68 µm B3: 0.78 - 0.89 µm B4: 1.58 - 1.75 µm	M: 0.61 - 0.68 µm B1: 0.50 - 0.59 µm B2: 0.61 - 0.68 µm B3: 0.78 - 0.89 µm B4: 1.58 - 1.75 µm	P: 0.50 - 0.73 µm B1: 0.50 - 0.59 µm B2: 0.61 - 0.68 µm B3: 0.78 - 0.89 µm
Imaging swath	60 km x 60 km to 80 km	60 km x 60 km to 80 km	60 km x 60 km to 80 km
Image dynamics	8 bits	8 bits	8 bits
Absolute location accuracy (no ground control points, flat terrain)	< 50 m (rms)	< 350 m (rms)	< 350 m (rms)
Relative internal distance accuracy (level 1B)	0.5×10^{-3} (rms)	0.5×10^{-3} (rms)	0.5×10^{-3} (rms)
Programmable	yes	yes	yes
Angle of incidence	±31.06°	±31.06°	±31.06°
Revisit interval (depending on latitude)	1 to 4 days	1 to 4 days	1 to 4 days

SPOT data have been continuously recorded over Australia by ACRES since May 1990, although not every pass is routinely acquired. Until July 2003 Australian SPOT satellite data were acquired and distributed by ACRES, since then Raytheon Pty Ltd has obtained distribution rights from SPOT Image (Raytheon, 2002).

2.2.5 Physical and biophysical interaction of vegetation and EM

When sunlight meets with an object on Earth, the electromagnetic waves are either absorbed, transmitted or reflected. The reflected component of the energy can be measured from ground, with airborne or with spaceborne sensors (passive Remote Sensing). Physical and biophysical interactions of the EM with the object under investigation determine their spectral response. Passive Remote Sensing of vegetated areas measures the spectral radiance from plant canopies in the 0.4–2.5 μm region of the electromagnetic spectrum (Tucker and Sellers, 1986).

During the photosynthesis process green vegetation uses light energy to convert carbon dioxide and water to carbohydrates and oxygen. Figure 2.3 shows a section of a green leaf. Photosynthetically active radiation (PAR) (0.4–0.7 μm) penetrates the upper epidermal surface of leaves (Gates et al., 1965; Knipling, 1970; Woolley, 1971; Gausman, 1974). The epidermis is protected by the cuticle, a water-repellent waxy layer which is almost completely permeable for light (Huss, 1984). Underneath the epidermis are the cells of the palisade parenchyma, in which pigments are concentrated. The dominant substances present are chlorophyll a (absorption at 360-440nm and 600-700nm), chlorophyll b (400-460nm), proto-chlorophyll (400-460nm) alpha-carotenoid (380-510nm) and xanthophyll (400-510nm) (Huss, 1984). The palisade parenchyma is the centre of photosynthesis and therefore visible light is absorbed here. Underneath are the cells of the spongy parenchyma with intracellular spaces, in which gases are exchanged. Here infrared light is strongly scattered on the walls of the cells, causing high reflectance of NIR light. The lower epidermis contains stomata, which regulate the gas exchange between the plant and the atmosphere (Huss, 1984).

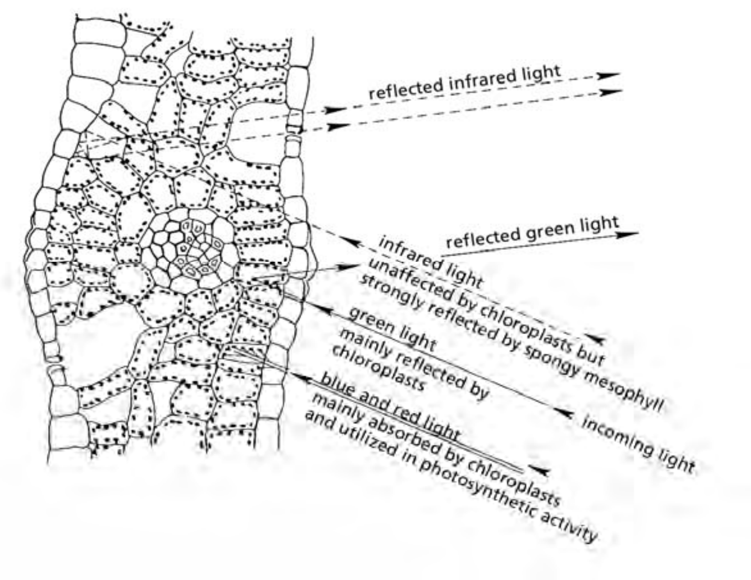


Figure 2.3: Green leaf section (modified from Kronberg, 1985)

Thus, absorption is high in the 0.4–0.7 µm region and reflectance and transmittance low. In the near-infrared part of the spectrum (0.7–1.3 µm), scattering by the structures within the leaves causes a high reflectance and transmittance since little absorption occurs (Tucker and Sellers, 1986). While liquid water is transparent to the PAR wavelengths, it is a strong absorber in the 1.3–2.5 µm region (Curcio and Petty, 1951). The water present in leaf tissues therefore causes absorption in this region.

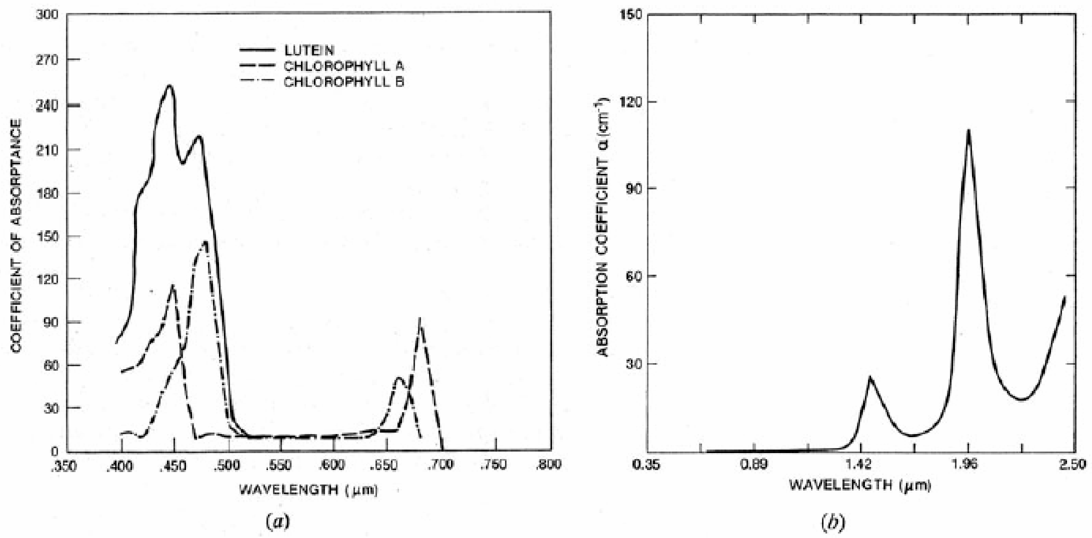


Figure 2.4: Coefficients of absorption for chlorophyll a, chlorophyll b, and lutein (a) and pure liquid water (b); (adapted from Tucker and Sellers, 1986)

Figure 2.4 shows the coefficients of absorption for chlorophyll a, chlorophyll b, the carotenoid lutein, and liquid water. Tucker (1978) proposed five primary and two transition regions between 0.4–2.5 µm where differences in leaf optical properties (scattering and absorption) and the background optical properties control plant canopy spectral reflectance (Figure 2.5). The regions are (Tucker and Sellers, 1986; Bronge, 2004):

- 0.4–0.5 µm, where strong spectral absorption by the chlorophylls and the carotenoids occurs
- 0.5–0.62 µm, where reduced levels of chlorophyll absorption occur (i.e. why green vegetation to our eyes appears "green")
- 0.62–0.7 µm, where strong chlorophyll absorption occurs
- 0.70–0.74 µm, where strong absorption ceases
- 0.74–1.1 µm, where minimal absorption occurs and the leaf scattering mechanisms result in high levels of spectral reflectance

➢ 1.1–1.3 µm, where the reflection decreases due to the liquid-water absorption coefficient increase from close to 0 at 1.1 µm to values of 4 at 1.3 µm (see Figure 2.4b)

➢ 1.3–2.5 µm, where absorption by liquid water occurs.

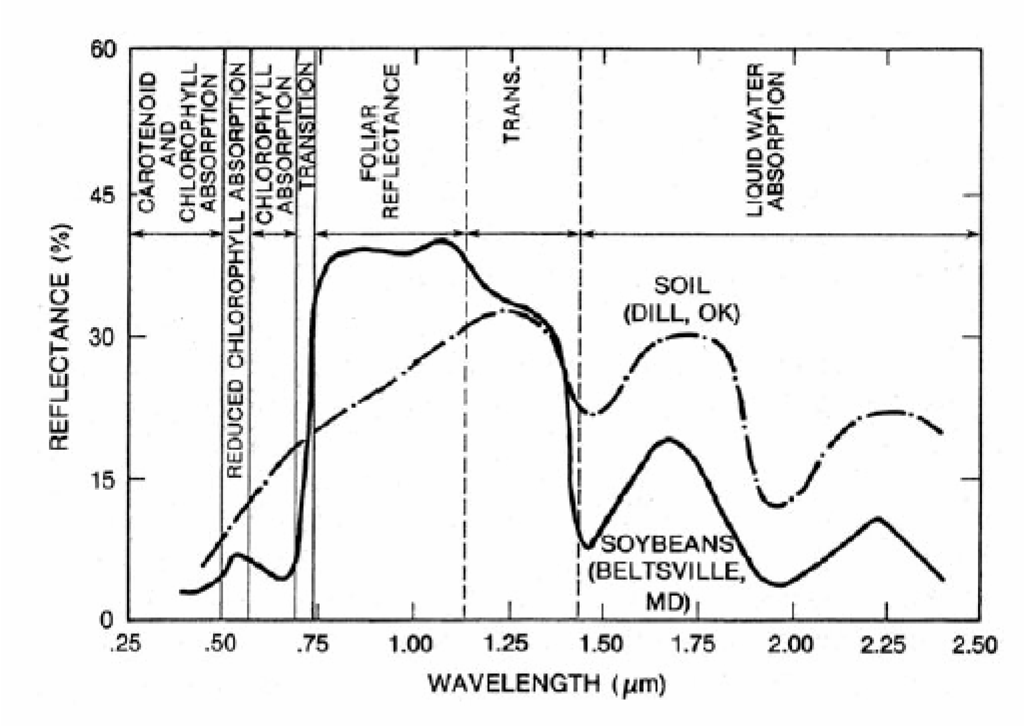


Figure 2.5: Delineation of the 0.4–2.5 µm region into spectral intervals where different biophysical properties of green vegetation control the reflectance of incident solar irradiance (From Tucker and Sellers, 1986)

The spectral character of the NIR plateau varies with vegetation type and condition. Crops, forests, and other types of vegetated ground cover tend to have different degrees of amplitude variations in the plateau region (largely due to liquid water in the plants, canopy architecture and light scattering considerations), most types of healthy vegetation exhibit first a gradually increasing and then a more variable decreasing reflectance with increasing wavelength in this region (Teillet et al., 1997).

2.2.6 Crop classification

Efficient crop management practices require accurate and rapid information about crop distributions. Commonly, multispectral remotely sensed images are used to distinguish crop types on the basis of their spectral properties (Mather, 1999). However, such analysis involving single-date images has the drawback that, since maximum discrimination between different crop types occurs at different stages in the growth cycle, not all differences are incorporated in the procedure. In addition, the temporal 'profile' of the spectral reflectance curve of each crop is not taken into account. Such profiles may be of considerable value in discriminating between crop types, which may be difficult to distinguish at certain points in the growth cycle (Vieira et al., 2003). A solution is to use multitemporal images for crop monitoring (Badhwar et al., 1982). For most current multitemporal classification techniques, a correspondence of time to growth state is established for each possible crop category that minimizes the smallest difference between the given multispectral-multitemporal vector and the category mean vector indexed by growth state (Haralick et al., 1980). Badhwar et al. (1982), Badhwar (1984), Haralick et al. (1980), Lambin and Strahler (1994) and Ortiz et al. (1997) also considered the problem of characterizing the temporal dimension.

2.2.7 Selected Vegetation Indices and their use in mapping crop parameters

The concept of using combinations of red and near infrared measurements to estimate biophysical parameters of vegetation was first introduced by Jordan (1969) who used a simple ratio of the canopy transmittance to derive leaf area index.

Table 2.3 gives an overview of selected vegetation indices. These are the most commonly used vegetation indices in the literature, but since manifold empirically derived vegetation indices exist, it is not complete.

Table 2.3: Summary of selected Vegetation Indices

(modified from Sandison, 1999**,** Elvidge and Chen, 1995)

Index and Source	Name	Formula
RVI Jordan (1969)	Ratio Vegetation Index	$RVI = \frac{NIR}{RED}$
NDVI Rouse *et al.* (1973)	Normalised Difference Vegetation Index See (a) below	NDVI = (NIR-R) / (NIR+R)
DVI Tucker (1979)	Difference Vegetation Index	DVI = NIR - RED
SAVI Huete (1988)	Soil Adjusted Vegetation Index * See (b) below	$SAVI = \frac{NIR - RED}{NIR + RED + L}(1 + L)$
TSAVI Baret *et al.* (1989)	Transformed Soil Adjusted Vegetation Index **	$TSAVI = \frac{a(NIR - aREd - b)}{RED + aNIR - ab}$
SAVI2 Major *et al.* (1990)	Soil Adjusted Ratio Vegetation Index **	$SAVI_2 = \frac{NIR}{(RED + b / a)}$
WDVI Clevers (1988)	Weighted Difference Vegetation Index	$WDVI = \rho NIR - \gamma \rho RED'$
IPVI Crippen (1990)	Infra-red Percentage Vegetation Index	IPVI = NIR / (NIR + R)
PVI Richardson and Weigard (1977)	Perpendicular Vegetation Index **	$PVI = \frac{NIR - aRED - b}{\sqrt{1 + a^2}}$
ARVI Qi *et al.* (1994)	Atmospherically Resistant Vegetation Index	ARVI = NIR - RB / NIR + RB

MSAVI2 Qi *et al.* (1994)	Modified Soil Adjusted Vegetation Index Two	$MSAVI2 = (1/2)(2(NIR+1) - \sqrt{(2(NIR)+1)^2 - 8(NIR-R)})$
TVI Broge and Leblanc (2001)	Triangular Vegetation Index See (c) below	TVI = 0.5[120(R750-R550)-200(R670-R550)]

* L is a soil adjustment factor (in SAVI, it ranges from 0 to 1 and is normally used at .5) ** *a* and *b* are rock soil baseline from NIR vs. RED

(a) Normalised Difference Vegetation Index (NDVI)

Perhaps the best known of the vegetation indices is the normalized difference vegetation index (NDVI; Rouse et al. 1974). The NDVI normalizes the difference of the red (R) and near-infrared (NIR) band combination and is therefore a relative measure within the image data (versus absolute measure by single, calibrated bands). The NDVI is often (wrongly) used with the DN values of the red and near infrared band, and not with calibrated reflectance values (Paris, 1998).

NDVI = (NIR-R) / (NIR+R); this index has a range of -1 to +1.

The NDVI is commonly used in multi-temporal mapping of vegetation dynamics based on maximum-NDVI composites (Townshend et al., 1985; Holben, 1986; Gutman, 1989; Wiegand et al., 1991; Viovy et al., 1992; Loudjani et al., 1994), in particular on continental or global scales (Townshend and Justice, 1986; Townshend et al., 1994; Smith, 1994). NDVI values can vary significantly as a function of sensor calibration (Price, 1987; Goward et al., 1991), atmospheric conditions (Deering and Eck, 1987; Singh and Saull, 1988; Kaufman and Tanré, 1992; Myneni and Asrar, 1994), directional surface reflectance effects (Kirchner et al., 1981; Holben 1986; Lee and Kaufman, 1986; Paltridge and Mitchell, 1990; Koslowsky, 1993), and terrain relief (Teillet and Staenz, 1992; Burgess and Lewis, 1994). Special attention has also been paid to soil background effects and soil indices (Richardson and Wiegand, 1977; Baret et al., 1989; Major et al., 1990; Huete and Tucker, 1991; Qi et al., 1994a,b). The NDVI, (like also the RVI), has shown to be sensitive to soil background. The problem of soil background in vegetation indices was described by Huete et al. (1985). Huete (1988) later developed a formula to account for soils called the Soil Adjusted Vegetation Index (SAVI):

(b) Soil adjusted vegetation Index (SAVI)

SAVI= (1+L)* ((NIR-R)/(NIR+R+L))

The SAVI uses a variable L depending on the amount of vegetation. Huete found that there might be two or three optimal L values for analysing very low vegetation (L = 1), intermediate vegetation (L = 0.5), or higher densities (L = 0.25). However, the adjustment of L = 0.5 offered a spectral index superior to the NDVI for the entire range of vegetation conditions studied (Huete, 1988). Bausch (1993) later tested the SAVI extensively and, like Huete, found SAVI to be more accurate than NDVI. Bausch reported that SAVI was (1) sensitive to a leaf area index (LAI) higher than 3, (2) was excellent in correcting a wet soil surface, and (3) minimized soil background throughout the growing season. Bausch concluded that using the adjustment factor L set at 0.5, the SAVI (1) minimized soil background effects throughout the entire growing season, (2) was independent of planting and effective cover dates, (3) was sensitive to slow and fast plant growth induced by weather anomalies and nutrient deficiencies, and (4) responded to leaf loss caused by hail and by various forms of plant stress induced by insects, disease, and water deficit (Wright et al., 2000).

(c) Broge and Leblanc (2001) developed the Triangular Vegetation Index (TVI), which is meant to characterize the radiant energy absorbed by leaf pigments in terms of the relative difference between red and near-infrared reflectance in conjunction with the magnitude of reflectance in the green region. TVI is determined as the area defined by the green peak, the near-infrared shoulder, and the minimum reflectance in the red region. It is formulated as:

$$\mathbf{TVI = 0.5*[120*(Reflectance_{750}-Reflectance_{550}) - 200*(Reflectance_{670}-Reflectance_{550})]}$$

The general idea behind TVI is based on the fact that the total area of the triangle (green, red, near infrared) will increase as a result of chlorophyll absorption (decrease of red reflectance) and leaf tissue abundance (increase of near-infrared reflectance) (Broge and Leblanc, 2001).

The theoretical foundation of vegetation indices has been well examined (Asrar et al., 1989; Baret and Guyot, 1991; Myneni et al.,1995a,b; Qi, 2001). Vegetation indices are affected by plant and measurement conditions, therefore field validation studies for various plant species, locations, and environmental conditions are needed to derive useful, robust semi-empirical relations. An overview of numerous studies relating spectral vegetation indices empirically by ground measurements to vegetation properties follows.

- various above-ground biomass measures (Pearson and Miller, 1972; Kauth and Thomas, 1976; Richardson and Wiegand, 1977; Tucker, 1979; Elvidge and Lyon, 1985; Price, 1992; Steven, 1998; Jago et al., 1999)
- fPAR (fraction of Absorbed Photosynthethical Active Radiation) (Asrar et al., 1984; Hatfield et al, 1984; Sellers, 1985, 1987, 1989; Choudhury, 1987; Baret and Guyot, 1991; Goward and Huemmerich, 1992; Myneni and Williams, 1994; Chen, 1996; Inoue et al., 2001)
- leaf area index (LAI) (Holben et al., 1980; Asrar et al, 1984, 1985b; Hatfield et al, 1985; Badhwar et al., 1986; Clevers, 1988, 1989; Spanner et al., 1990; Baret and Guyot, 1991; Chen, 1996)
- crop moisture variations (Peñuelas et al., 1995; Russ 1993)
- leaf pigment concentrations and chlorophyll levels (Blackburn, 1998a; Blackburn and Steele, 1999; Miller et al., 2002; Jago et al., 1999)
- carbon dioxide (Tucker et al., 1986; Cihlar et al., 1992)
- biophysical plant canopy properties (Pinty et al., 1993)
- assessment of crop or vegetation stress (Blackburn, 1998b; Dawson et al., 1998)
- detection of crop phenology (Badhwar and Henderson, 1981)
- crop type or species identification (Asner et al., 2000)
- land cover characterization (Goetz et al., 1985; Friedl et al., 1994; Lyon et al., 1998; Thenkabail et al., 1999; Thenkabail et. al., 2000)
- assessment of carbon fluxes (Fassnacht et al., 1997)
- primary productivity (Asrar et al, 1985a; Tucker and Sellers, 1986)

- yield (Aase, 1979; Tucker et al., 1985; Bartholome, 1988; Rudorff and Bastista, 1991; Wiegand et al., 1991; Quarmby et al.,1993; Maselli et al., 1993; Cabezon and Taylor, 1994; Smith, 1994; Smith et al.,1995; Murthy et al., 1996; Hamar et al., 1996; Rasmussen, 1996 and 1998; Clevers, 1997; Hayes and Decker,1996 and many more -for further examples see references in Genovese, 1994; Rasmussen, 1998; Moulin et al., 1998).

2.2.8 The use of Remote Sensing to map pests, diseases and weeds

Plant damage can be caused by many agents, such as insects, disease, insufficient or excess water and nutrients, mechanical, and chemical damage. In many cases, this damage is manifested in changes in above-ground foliage, such as tone or colour of leaves, leaf condition (wilting or distortion), leaf area (including defoliation), and leaf or stem orientation (such as lodging) (Inoue, 2003). Stress caused by the infestation results in reflectance changes in the vegetation which can then be detected with the Remote Sensing data and allow accurate, timely means of assessing the extent of the damage and identifying management units for time-critical material applications (Inoue, 2003).

Hatfield and Pinter (1993) described Remote Sensing observations of crop stress brought on by diseases, insects and weeds. Toler et al. (1981) used false colour NIR photography to detect *Phymatotrichum* root rot of cotton and wheat stem rust. Penuelas et al. (1995) found that increasing infestations of mites in apple trees caused a decrease in the leaf chlorophyll concentration and an increase in the carotenoid/chlorophyll a ratio. These chemical changes were detected by hyperspectral reflectance measurements. In fungal and mildew infected leaves, changes in remotely sensed reflectance have been detected before symptoms were visible to the human eye (Malthus and Madeira, 1993; Lorenzen and Jensen, 1989). Furthermore, spectral properties were assessed to detect insect damage in wheat (Riedell et al., 2000), to detect spider mite in cotton (Fitzgerald et al., 2000), and to assist in insecticide application (Seal et al., 2000). Discrimination of diseases may be possible with knowledge of the physiological effect of the disease on leaf and canopy elements. For example, necrotic diseases can cause a darkening of leaves in the visible spectrum and a cell collapse that would decrease near-infrared reflectance. Chlorosis inducing diseases (mildews and some virus) cause marked changes in the visible reflectance (similar to N deficiency) and other diseases may be detected by their effects on canopy geometry (wilting or decreases in Leaf Area Index LAI) (Inoue, 2003).

Thorp and Tian (2004) reported in their review on Remote Sensing of weeds that since weeds grow in definite patches, successful delineation of patch boundaries creates a potential for applications of herbicide on a site-specific, need-only basis. Remote Sensing has been widely explored as a tool for detection and mapping of weeds in agricultural crops (Lamb and Brown, 2001; Moran et al., 1997; Zwiggelaar, 1998). By detecting the location of weeds within an agricultural field, Remote Sensing provides a means for the development of weed maps, such that herbicide applications can occur on a site-specific basis (Brown and Steckler, 1995; Stafford and Miller, 1993; Thompson et al., 1991). Reductions in herbicide use as a result of this practice reduce management costs for growers (Medlin and Shaw, 2000) and promote environmental friendliness (Timmermann et al., 2001).

Carefully controlled experiments have shown that homogeneous plots of crops and weeds are distinguishable in Remote Sensing images (Menges et al., 1985; Richardson et al., 1985). Remote detection of weeds growing naturally in a post-emergence crop setting was found to be a more difficult task. Most researchers have used classification algorithms to delineate weed patches based on statistical variability in the spectral response of soil, crop, and weed/crop canopies. Classification algorithms worked well for pre-emergence sensing of weeds because the response of bare soil is, in general, spectrally separable from a weed spectral response (Lamb and Weedon, 1998; Lamb et al., 1999). However, for post-emergence weed sensing, the ability of a classification to accurately detect weeds is lessened because weeds and crops exhibit similar spectral characteristics (Lamb and Brown, 2001). Hatfield and Pinter (1993) suggested that a better understanding of the relationships between infestations, weed species, and crop growth stage was necessary before Remote Sensing could be successful in sensing weeds within crop canopies. Possibly weeds can also be mapped with Remote Sensing if images are acquired at a specific times during the season when weed colouring is particularly distinctive (i.e., during flowering) (Inoue, 2003).

2.2.9 The use of Remote Sensing for soil mapping

Baumgardner et al. (1985) provided a detailed review of the reflectance properties of soil. Nielsen et al. (1995) identified several of the most important soil fertility attributes that could be mapped and managed for improved yield: available soil nitrogen or some other macro or micro plant nutrient, relative position and slope of the terrain, and soil organic matter content.

Soil organic matter

Soil organic matter content has been directly related to the efficacy and rate of fertilizer applications, as well as to crop yield and other soil variables such as phosphorus. Radiometric measurements of bare soils are useful to directly extract information about soil physical properties such as organic matter (Dalal and Henry, 1986; Zheng and Schreier, 1988; Shonk et al., 1991; Bhatti, et al., 1991; Robert, 1993; Tyler, 1994).

Soil salinity

Verma et al. (1994) found that better results could be obtained by combining reflectance and temperature information, particularly for discrimination of the similar reflectance properties of salt-affected soils and normal sandy soils. Wiegand et al. (1996) have used soil and plant samples, spectral observations, with unsupervised classification to map soil salinity and yield at salt-affected cropped fields. Further work in mapping soil salinity with Remote Sensing tools has been reported by Wang et al. 2002; Dehaan and Taylor, 2002). Soil types and dryland salinity have been distinguished, using airborne radiometrics (Beasley et al., 1998; Coppa et al. 1998; Newnham et al., 1998; Woodgate et al., 1998)

Other soil parameters

Inoue (2003) noted that images obtained when soils were bare could be used to map soil types relevant to Precision Farming. Maps of spectral variability of bare soil may prove useful for revision of maps of management units (Inoue, 2003).

Surface reflectance information has been related directly to variability in

- soil clay content (Sudduth et al., 1995; Chen et al., 2000)
- loess thickness (Milfred and Kiefer, 1976)
- soil calcium carbonate content (Leone et al., 1995)
- soil nutrients -particularly those associated with soil texture and drainage (Thompson and Robert, 1995)
- soil nitrate levels (Adsett and Zoerb, 1991)
- iron oxide content (Coleman and Montgomery, 1987)
- soil texture classes with similar responses to water and fertilizer (King et al., 1995)
- Soil thermal information has been linked with variations in soil moisture content (Idso et al., 1975; Salisbury and D'Aria, 1992)
- soil compaction (Burrough et al., 1985)
- soil organic content (Salisbury and D'Aria, 1992)
- particle size (Salisbury and D'Aria, 1992)
- the presence of abundant minerals other than quartz (Deguise and McNairn, 2000)

Problems mapping soil with Remote Sensing

Despite the relations among soil reflectance and soil properties, and having shown potential for the automated classification of soil mapping units (Leone et al., 1995), remotely sensed images are not currently being used to map soil characteristics on a routine basis (with the exception of high and medium altitude aerial photographs that serve as base maps for soil surveys). This is because the reflectance characteristics of the desired soil properties (e.g., organic matter, texture, iron content) are often confused by variability in soil moisture content, surface roughness, climate factors, solar zenith angle, and view angle (Inoue, 2003). This is particularly important for mapping agricultural soils supporting various cultivation practices. For example, Leek and Solberg (1995) showed that images of surface reflectance acquired during times of greatest ploughing activity could be used to map tillage.

2.3 The emergence of Precision Farming and the relevance of Remote Sensing information

2.3.1 Definition of Precision Farming

Blackmore (2000) defined Precision Farming as the management of arable variability to improve the economic benefit and reduce environmental impact. Precision Farming is also known as prescription farming, site specific management and precision agriculture.

2.3.2 History of Precision Farming

The basis of precision agriculture - the spatial and temporal variability in soil and crop factors within a field - has been known for centuries. In the past centuries, the very small field size and their delineation by natural boundaries, such as water courses and change of soil type, may have enabled farmers to vary treatments manually (Stafford, 2000). However, with the enlargement of fields, intensive production and mechanization in the latter half of the 20th Century, it was not possible to take account of within-field spatial variability without a significant development in technology (Stafford, 2000). Although one could quote work earlier in the 20th Century (Linsley and Bauer, 1929; Eden and Maskell, 1928) as setting the first seeds of precision agriculture, it was mainly due to Johnson et al. (1983), who developed the concept of custom prescribed tillage. They were visionaries in terms of how automation, sensing systems, location systems and information technology would transform agricultural crop production as the technology became widely available. They stated that future machinery used in production agriculture will be automatically controlled to prescribe cultural practices, based on soil, crop and climate. Some soil and crop information may be sensed on-the-go and stored in a computer on board the prime mover or field machine. This computer, in turn, could be programmed to make real-time decisions based on this information to control cultural practices such as fertilizer, herbicide and pesticide application. Important to this concept is a general spatial position-sensing system that can pinpoint the position of a machine in the field at any time (Stafford, 2000).

2.3.3 Technology used in Precision Farming

The pivotal technology that drove the development of the precision agriculture concept was the establishment, in the late 1970s, of the Global Positioning System (GPS) based on a constellation of satellites placed in orbit by the US Department of Defence. This system provided the potential to determine position (latitude, longitude and altitude) anywhere on earth, 24 hours per day, to an accuracy of a few centimetres (Stafford, 2000). In the past, the civilian signal was degraded, and a more accurate Precise Positioning Service was available only to the United States military, its allies and a few others, mostly government users. However, on May 1, 2000, then US President Bill Clinton announced that this "Selective Availability" would be turned off, allowing all users to enjoy nearly the same level of access, with a precision of position determination of less than 20 metres (Whitehouse, 2000). With such information available to field machines, the treatment applied during field operations could be related to highly localized requirement within the field (Stafford, 2000).

Pedersen (2003) summarized different components used in Precision Farming (Fig. 2.6). Precision Farming further benefited from the emergence and convergence of several other technologies such as geographic information system (GIS), miniaturized computer components, automatic control, mobile computing, advanced information processing, telecommunications and in-field and remote sensing (Gibbons, 2000).

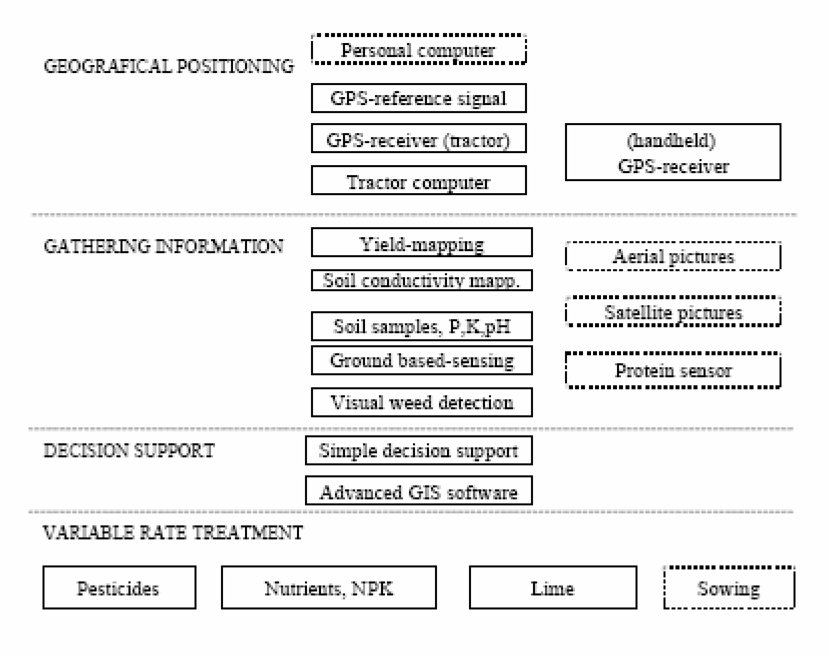


Figure 2.6: Various Precision Farming technologies (from Pedersen, 2003)

Geographic Information Systems and Decision Support Systems

Multiple information layers are necessary to make site specific management decisions. McBratney and Whelan (2001) determined the key data layers for site specific management to be crop yield, quality of yield, soil physical and chemical attributes, terrain, weeds and diseases. Furthermore - in the Australian environment - soil moisture is often a yield limiting factor, so soil and landscape attributes that govern water flow and retention are vital. Once information on yield variability is available, it must be analysed for making management and application decisions. The challenge is to develop variable rate technology (VRT) decision criteria (Kitchen et al., 1995) in the form of decision support systems (DSS), and to understand the relation between crop and soil variability and management strategies (Colvin et al., 1995). GIS is required to overlay and spatially reference the data and DSS are vital to process the data. Tevis (1995) suggested several options ranging from simply applying a threshold function to a specified attribute layer (Tevis and Searcy, 1991) to using an expert system with several agronomic attribute layers (He et al., 1992). Managing crop and soil conditions that vary in both the spatial and temporal domain will require expert systems to analyse data (determine cause/effect) and make integrated management decisions (Fixen and Reetz, 1995). McGrath et al. (1995) described a packaged system for fertility management that includes automated data collection and analysis, an expert system for evaluating data in combination with other information to suggest management options, and automated applicators to carry out the management program. This package has individual sub-models for phosphorus, potassium, organic matter, and soil moisture, where static and dynamic information is required for each. This modular approach in a GIS environment appears to be the norm for development of expert systems and decision support systems for site specific management (Brown and Steckler, 1995). Griffith (1995) proposed a merging of many models to define specialized portions of the behaviour of the total production process. Other decision aid models have been developed for managing specific crops such as sorghum (SORKAM, Vanderlip et al., 1995), and cereals (CERES with DSSAT, Hoogenboom et al., 1994; Booltink and Verhagen, 1996) (Moran et al., 1997). McBratney and Whelan (2001) noted that in Australia DSS for precision agriculture are still in their infancy. Crop simulation models seem to be the best way to translate soil and environmental information into production estimates. Such models are still not well “spatialised” and it may be that simpler, spatial meta-models need to be constructed in the meantime to supply decision support (McBratney and Whelan, 2001).

Variable Rate Technology

Using the within field variability information collected from site samples or other data inputs, such as remotely sensed data, variable rate technologies (VRT) apply the appropriate chemical inputs to the affected sites in the field. Brisco et al. (1998) noted that VRT and yield monitors are an essential component of site specific management and their use is becoming more prevalent, particularly among producers with large land holdings or high value cash crops. For example, VRTs can mix custom fertilizer blends and apply the correct combination and amount to a site. In the case of weed infestations for example, flow-rate sprayers apply the appropriate type and rate of herbicide, only to those sites affected. Discussions of various aspects of the use of VRT in precision agriculture can be found in Schueller (1992); Ferguson et al. (1995); Mortensen et al. (1995); Hanson et al. (1995); Searcy (1995); Fleischer et al. (1996).

2.3.4 Information needs of Precision Agriculture and complimentary Remote Sensing capabilities

The beneficial use of spatial imagery in agriculture for crop management has been known as early as 1929 when aerial photography was used to map soil resources. Moran et al. (1997) summarized an extensive review of the potential and limitations of Remote Sensing data for precision crop management. Based on Precision Crop Management systems, they identified eight areas where remotely sensed imagery could provide missing information. These relate to zone management, crop yield prediction, soil type mapping, seasonal variability and causes, production of Digital Elevation Models (DEMs), and aerial imagery for quick damage assessment and control.

2.3.5 Status assessment of the use of Remote Sensing for crop monitoring

Pedersen (2003) reviewed in his thesis "Precision Farming – Technology assessment of site-specific input application in cereals" the current use Remote Sensing for Precision Farming. He concluded that Remote Sensing with satellites is at a pre-commercial stage. Satellite images are in principle commercially available but the data require further processing to be utilized in a GIS. Furthermore, satellite images are only available in very large sizes, which is very costly to handle for the individual farmer. Should it be nonetheless possible for a group of farmers or a farmers association to share the image costs, someone still has to process and deliver the images. Pedersen (2003) reported obstacles with the delivery times of images. Even though satellites acquire images frequently, in his experience farmers should expect a turn-around time of 60 days, which is too lengthy to be useful for crop management (Pedersen, 2003).

2.3.6 Review of currently available crop monitoring systems

In the last 2-3 years the availability and electronic delivery speed of satellite images has improved. Precision Farming services has been a main user group identified by the operators of commercial (high resolution) satellite companies and they have established their own service provider companies or formed strong alliances with new emerging companies (with personnel mainly from the research background, complementing their imagery with processing algorithms). In 1998 (when the prototype trial reported in this thesis took place) no satellite monitoring service was available to Australian broad acre grain farmers. Today, however two companies have been identified, that are embarking to offer services to limited areas in Australia. Furthermore some recent initiatives of international organizations have been identified, some of which have an interest to expand into Australia (I. Coppa, personal knowledge).

BroadacrePrecise

Operated by Agricon, Canberra, which was formed in 1992 as a partnership between an academic (and his family) from the University of Canberra, and the University of Canberra. Since March 2001, CropMAPS derived from satellite imagery for the rice, sugar and cotton industry, and broad acre cereals and pulses maps are available on the internet. BroadacrePrecise is delivered via the ERMapper Image Web server and is available for parts of New South Wales, South Australia and Victoria. The broad acre vigor maps cost 2.20/ha (Button, 2001; Agrecon, 2005).

AgriView Crop Imaging

Operated by Terrabyte Services (based in Wagga Wagga, NSW; company was established in Oct 2000; company founders came from Charles Stuart University in Wagga Wagga). In the past airborne video images have been used for Precision Farming application with specific focus on rice, cotton and viticulture. Recently the company has started using airborne image artefact removal algorithms from EADS Atrium (developers of the European Farmstar) and offers vegetation index maps from Quickbird and Ikonos as well as selected Farmstar products (using SPOT) (Terrabyte, 2005).

FARMSTAR

Is a consortium operated by EADS Astrium, Infoterra (Infoterra was formed 2001 by integrating the 'Earth Observation Services' division of Astrium GmbH, Germany and the National Remote Sensing Centre Ltd. (NRSC Ltd.), UK) and Syngenta. It has been available since 2002; the company promises to provide information on paddocks within 5 days of acquisition by satellite (SPOT). Supported crop types are wheat (10 Euro/ha), maize, rapeseed and sugar beet. The areas serviced are parts of France, Germany and England. The customer receives 3-6 recommendation maps per season, depending on crop type. The company has access to SPOT archives (Infoterra, 2005; SPOT 2005).

FARMSAT

Operated by GeoSys, Farmsat is composed of different modules, one being a ten day Vegetation Index at a regional or country level (Agriquest). The maps are available for most of Europe. The spatial resolution of this product is too low to be used for Precision Farming purposes. Furthermore mapping, zoning and scouting services are offered. The zoning product SAMZ "satellite-derived management zones" was developed with a grant from Stennis Space Center, Mississippi (USA); it is based on archived satellite data, using wavelet theories to combine temporal and space variability to extract management zones. Together with the Mosaic company, Geosys also offers the InSite product for variable rate nutrition maps and yield potential maps; this service is available for parts of England, France and Iowa (US). The company has offices in Toulouse, France and Minneapolis and Washington, USA; the products are linked with Syngenta in Europe and the US and Cargill Crop Nutrition in Australia (Farmsat 2005; Syngenta, 2005).

SATSHOT

Is operated by Agri ImaGIS (Maddock, ND USA). The service is available in the USA, and uses Landsat Data Archives. The Landscout RX software is available for data administration and variable rate applications and calculates a Vegetation Greenness Index from the satellite data. Image data are sold in Image paks, per square mile, (US$25-50 per square mile, per image date) and delivered by a web server. The company has been involved in Remote Sensing applications for agriculture since 1998. (Satshot, 2005).

Crop and Range Alert System Project

The project is operated by the Upper Midwest Aerospace Consortium (UMAC). UMAC's Crop and Range Alert System Project is funded by Raytheon, NASA and Digital Globe. The number of end users participating in this project has grown from 30 in year 2000 to 75 in 2001, 128 in 2002 and 243 in 2003. To study participants (TeamExpress members), UMAC offers analysed satellite data. The study advocates the learning community principle and participants are trained in workshops (Seelan et al., 2003). Imagery and derived products from AVHRR, MODIS, Landsat, IKONOS, QuickBird, Hyperion and aerial platforms are delivered to farmers, ranchers, and land managers covering Montana, Wyoming, Minnesota, North Dakota and South Dakota. Furthermore climate data (temperature and precipitation) and climate variability and change data are available. The project has alliance with Agrowatch from Digital Globe (UMAC, 2005).

Agrowatch

Is operated by EarthMap Solutions (EMS, located in Colorado, USA) since 2001. The company was formed by Resource 21 and Digital Globe (Quickbird operator). Services offered are Soil Zone Map, Green Vegetation Map (Green Vegetation Index 0-100), Scout Aide Change Map, Yield Trax (yield monitoring without Precision Farming equipment on combine harvester) and canopy density maps for viticulture or orchards. Image data used are from QuickBird, SPOT, Landsat, MODIS, Ikonos and IRS in areas on 4 continents (Earthmapsolutions, 2005).

2.4 Issues and challenges

There are specific issues to be considered when designing a crop monitoring system. Furthermore the need exists for several barriers to be overcome so that Precision Farming technologies can be widely implemented in a fast pace.

2.4.1 Near real time data delivery

Paris (1998) reported that during the management intensive times of the growth cycle (depending on crop type) the frequency of coverage needs to be at least weekly (perhaps twice-weekly) as this is the frequency of management decisions. Most importantly, since agriculture is very dynamic, the satellite-derived products and information needs to be delivered to end-users within in near real time (24-48 hours after acquisition). To fulfil those quick turn-around times, it is necessary to deliver data digitally (even though a lot of farmers still prefer hard copies) (Paris, 1998; Seelan et al., 2003; Jackson 1984).

2.4.2 Imagery

Precision Farming requires information on crop condition frequently throughout the growing season and often at high spatial resolution (Jackson, 1984; Seelan et al., 2003). Jackson (1984) requested a spatial resolution of 5–25 meters for farm management. Paris (1998) determined that for within-field mapping of crop conditions a spatial resolution of 1-10 metres pixel sizes is needed. Cloud cover often reduces the amount of available satellite imagery, hence making it difficult obtaining imagery at the required point in time. However with the recent launch of several high resolution satellites, chances have increased that successful image acquisition can take place.

2.4.3 Need for radiometric and atmospheric correction

When working with satellite images throughout a whole crop cycle, it is necessary to acquire images from several dates, and consequently different sun angle and atmospheric conditions. For the retrieval of crop parameters from multi-temporal data it is essential to apply radiometric and atmospheric corrections (Deering and Eck, 1987; Singh and Saull, 1988; Kaufman, 1989; Kaufman and Tanré, 1992; Tanré et al., 1992; Myneni and Asrar, 1994; Vermote et al., 1996). Richter (1996) has developed an atmospheric correction algorithm which is suitable for satellite sensors with spatial resolution like Landsat Thematic Mapper (TM) and SPOT. The algorithm works with a catalogue of atmospheric correction functions stored in look-up tables. It consists of interactive and automatic parts. The interactive phase serves for the definition of a reference target as haze and cloud; the automatic phase first calculates the visibility of the reference areas of the selected atmosphere. Haze removal is performed by histogram matching the statistics of the haze regions to the statistics of the clear part of the scene for each sector and each channel. In the last step of the procedure, the ground reflectance image including the adjacency correction is calculated, and the computation of the ground brightness temperature image.

2.4.4 Lack of localized scientifically validated models

Zhang et al. (2002) found a lack of rational procedures and strategies for determining application requirements on a localized basis. Farmers who gather data based on site-specific tools (GPS, yield mapping and sensors) have a limited number of agronomic models to evaluate this spatial information and thereby adapt their decisions within the field (Thomsen, 2001; Acock and Pachepsky, 1997). The need for scientific validated models exists also for the retrieval of reliable biophysical characteristics from Remote Sensing data for a known crop type (Bullock et al., 2000); Currently there is information overflow on farm level; it is necessary to convert Precision Farming gained knowledge into management decisions; This problem has to be overcome by developing data integration tools, expert systems, and decision support systems (Zhang et al., 2002). Jackson (1984) suggested for farm management the integration of Remote Sensing systems with meteorological and agronomic data into expert systems. The refinement of models to local requirements (crop type and local conditions) is needed.

2.4.5 Development of technology

Brisco et al. (1998) suggested that universities and academic institutions need to play a fundamental role in the long-term research issues as well as the training programs for introducing the geomatics technologies to the agricultural community. The private sector has a responsibility for market development, product credibility, and customer satisfaction. The public institutions, at all government levels, need to help by coordinating the various activities involved in developing and implementing precision agriculture and by providing support programs to achieve this objective. All groups should participate in long term needs assessment and strategic planning in order to continue and develop this technology (Brisco et al. 1998).

2.4.6 Technology transfer

Unlike in the case of large-scale crop inventory, the interested party is the farmer himself, who often lacks familiarity with the use of imagery. Farmers are generally not aware of what is available, and how to interpret it. Crop consultants and extension agents are equally unfamiliar with the technology. The end users are rarely involved in product development, resulting in a gap in understanding their needs. Precision farmers are familiar with GIS and GPS technologies, but lack the training needed to extract information from imagery (Seelan et al., 2003). Zhang et al. (2002) also identified the lack of technology-transfer channels and personnel and found that educational programs involving researchers, industry, extension specialists, and consultants are urgently needed.

2.4.7 Adoption of the technology

The fundamental challenge in developing a new farming system is to have it adopted and maintained by farmers. In Australia, Cook et al. (2000) found that farmers are adopting Precision Farming technologies more slowly than expected. They attribute the slow adoption to four factors:

- cost of adoption,
- lack of perceived benefit from adoption,
- unwillingness to be early adopters, and
- lack of technology delivery mechanism.

Cost of adoption

According to Pedersen (2003), the positive impact of Precision Farming on farm economics has not yet been demonstrated. Specific tools for Precision Farming are costly and the economic benefits are not clear (Audsley 1993; Bullock 1998; Schmerler and Basten 1999; Schmerler and Jurschik 1997 and Swinton and Lowenberg- DeBoer 1998).

Lack of perceived benefit from the adoption

Mansfield, (1963) reported that the greater the potential profitability, the faster the dissemination of new technologies and their adoption. Few cost–benefit studies on a localized scale are available to convince the average farmer of the benefits of Remote Sensing (Seelan et al., 2003).

Unwillingness to be early adopters

There is strong evidence that all over the world, most farmers are 'risk-averse' (Antle, 1987; Bardsley and Harris, 1987; Binswanger, 1980; Bond and Wonder, 1980; Myers, 1989; Pluske and Fraser, 1996). This is evident from the observation that they will not leap into large-scale adoption of a new innovation. Rather, they generally employ a small-scale trial which is perhaps the most important phase in determining final adoption or disadoption (Pannell, 1999). In order to trial a new farming system, the farmer needs awareness of the innovation. In this context, 'awareness' means not just awareness that an innovation exists, but awareness that it is potentially of practical relevance to the farmer (Pannell, 1999). The farmer also needs to have perception that the innovation is worth trialling. Conducting a trial incurs costs of time, energy, finance. To be willing to trial an innovation, the farmer's perceptions of it must be sufficiently positive to believe that there is a reasonable chance of adopting the innovation in the long run (Pannell, 1999). The farmer furthermore needs to have the perception that the innovation promotes his objectives. Self interest in this context is considerably broader than merely profit. It may, for example, include objectives related to risk, leisure and environmental protection. Nevertheless, profit is a particularly important element of self-interest. There is also strong evidence that even for innovations oriented towards resource conservation, economic considerations are the most important determinants of actual adoption decisions (Marsh et al., 1995; Cary and Wilkinson, 1997; Sinden and King, 1990). If the existing technologies being promoted are not sufficiently profitable (or more generally beneficial), new technologies must be develop, or the existing technologies must be more attractive through such means as subsidies, tax concessions or, in the extreme, taxes or legal penalties for non-adoption (Pannell, 1999).

Lack of technology delivery mechanism

Although the cost, lack of perceived benefit, and conservatism among farmers has indeed caused the slowness in adoption, the problem in delivering the Precision Farming technologies to farmers has been identified as the major obstacle. Delivering Precision Agriculture technologies to farmers requires knowledge and skills that most consulting agencies currently do not possess (Zhang et al. 2002). Therefore overcoming the conservatism and facilitating appropriate training of the consultancy sector seems essential for the success of Precision Farming applications.

Moran et al. (1997) propose the following model (Figure 2.7) for the successful implementation of Remote Sensing for Precision Farming applications.

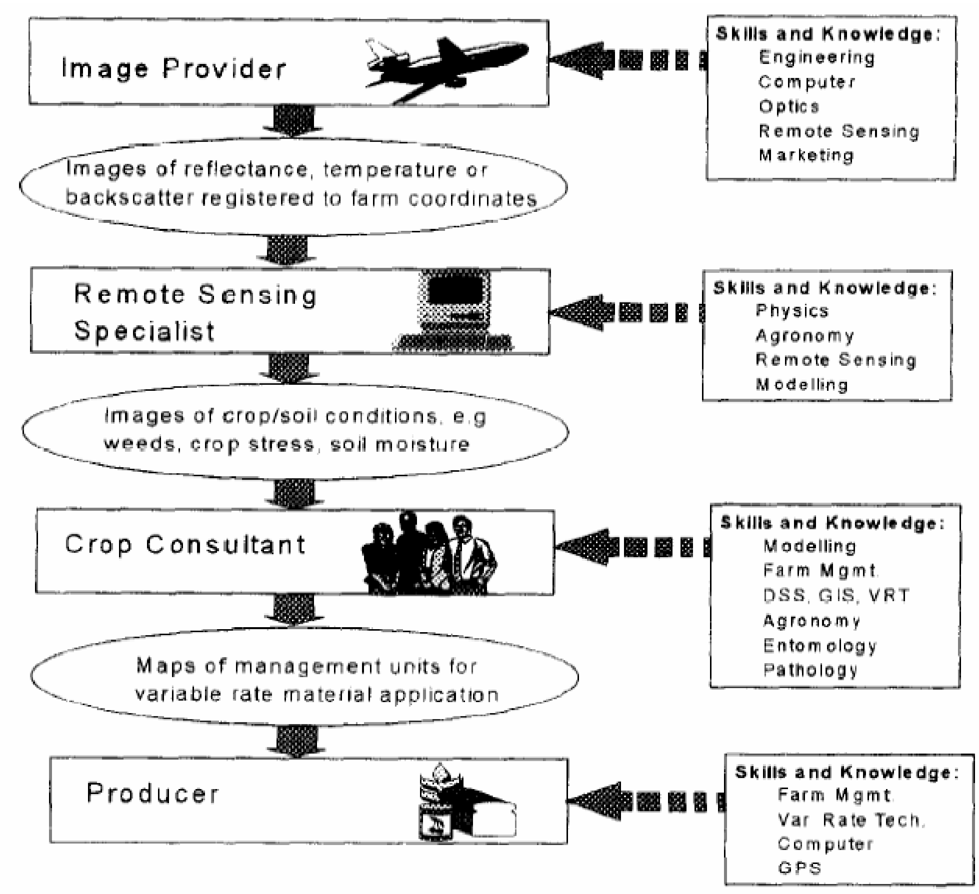


Figure 2.7: Processing steps of Remote Sensing images in Precision Farming (from Moran et al., 1997)

The cooperation of four different groups is required: Image providers acquire data at appropriate spatial, spectral and temporal resolution and deliver those near real time to Remote Sensing specialists for data processing. The derived products are delivered to crop consultants who in turn liaise with the end users (farmers and farm managers). The data are utilized for site specific management applications and decisions.

2.5 Significance of this research

Since this research started parallel developments have been made in the field of operational crop monitoring systems. This research is nevertheless important as it developed localized spatial models for various crop types and crop parameters for the region of south east Australia. In addition it was documented what problems could be observed in broad acre grain fields in this region.

Furthermore the research is significant as it developed a regional relevant crop monitoring system prototype with feedback of local Australian broad acre grain farmers. Information products and delivery mechanisms suitable for the south east Australian region were developed.

2.6 Conclusions

In this chapter aspects of Remote Sensing and precision agriculture were reviewed, in particular topics that overlap both fields. It was found that commercially operational Remote Sensing satellites, such as the SPOT satellite were available to monitor agricultural fields at sufficient temporal, spatial and spectral resolution. The successful application of optical satellite data and derived vegetation indices in the literature to map crop pests, diseases, weeds and various soil parameters were presented. Technologies used in Precision Farming, such as Global Positioning System, Geographic Information Systems, Decision Support Systems and Variable Rate Technology were discussed. Furthermore the contributions that Remote Sensing can make towards the information needs of Precision Agriculture were identified; these related to soil type and digital terrain mapping, identification of management zones, crop yield predictions, crop scout assistance to identify seasonal variability within fields and the causes thereof, as well as damage assessment. Various international initiatives were reviewed that have started since the commencement of this project and offer crop information derived from satellite imagery for Precision Farming. These initiatives were mainly commercial spin-offs from research institutes, backed by large satellite companies and have at least been partially funded with research grants from public money. Issues were identified that need to be progressed before satellite crop monitoring systems would be implemented by a wide user community; these concerns were delivery speed, image resolution and correction algorithms, localized scientifically validated crop models and the strategic R&D cooperation to develop technology and transfer knowledge to end users. Furthermore the challenges for the adoption of the technology in Australia were identified as the cost, perceived benefit and economic rewards to farmers; the adoption of the technology by the consultancy sector is also required.

Hence the successful implementation of Remote Sensing in Precision Farming requires the cooperation of image providers, Remote Sensing specialists, crop consultants and producers. This thesis focuses on the contributions that Remote Sensing specialists can make to the monitoring of the grain crops barley, canola, chickpea, lentils and wheat in south east Australian conditions.

3. Background and context for the study

3.1 Introduction

The scope of the thesis limits the work to an experiment in the Gooroc area of south east Australia and the five crop types. The purpose of this chapter is to give the reader relevant background information regarding the test site and crop types that were investigated. Therefore the physio - geographic parameters, such as geology, soils and climate are described. Furthermore the crop industry in Victoria as well as summary information related to the crop types are given in the context of the study project.

3.2 The ALMIS concept

Precision farming tools have recently become available in Australia. Most “precision farmers” produce yield maps at harvest. These yield maps are valuable assets to delineate crop management zones after several years. However when the yield map is obtained it is too late to apply management techniques that would address problems in the crop specific to the current season. Therefore a prototype system was devised that used commercially available satellite imagery to monitor the crop development throughout the growing season. The system was tested with 25 farmers in the Gooroc area. Problems in crops were detected and the information from the satellite images assisted the farmers to adjust their management decisions. The project was named **ALMIS**. ALMIS is an abbreviation for **A**gricultural **L**and **M**anagement **I**nformation **S**ystem (Coppa and Andrews, 1997).

3.3 South east Australian case study region

Gooroc (geographic location: 36°23’ S, 143°09’ E) was selected to be the trial site for the ALMIS Project in south east Australia. The site was located between the country towns of St Arnaud, Charlton and Donald, known as the Eastern Wimmera, about 270 km to the north west of Melbourne, the capital of the State of Victoria (Figure 3.1).

Figure 3.1: Map of Australia, Victoria and location of the test site (from Aigner, 1999)

Reasons for the selection of the Gooroc site were numerous including the presence of homogeneous grain crop fields (average field size 115 ha), reasonably flat terrain (this was particular important for the ERS radar studies), and a supportive and accessible farming community. Figure 3.2 shows a SPOT 4 satellite image (B= Band1, G= Band 2, R= Band 3) of the test site from 30/06/1998 (this was also the first image of Australia of the in 1998 commissioned SPOT 4).

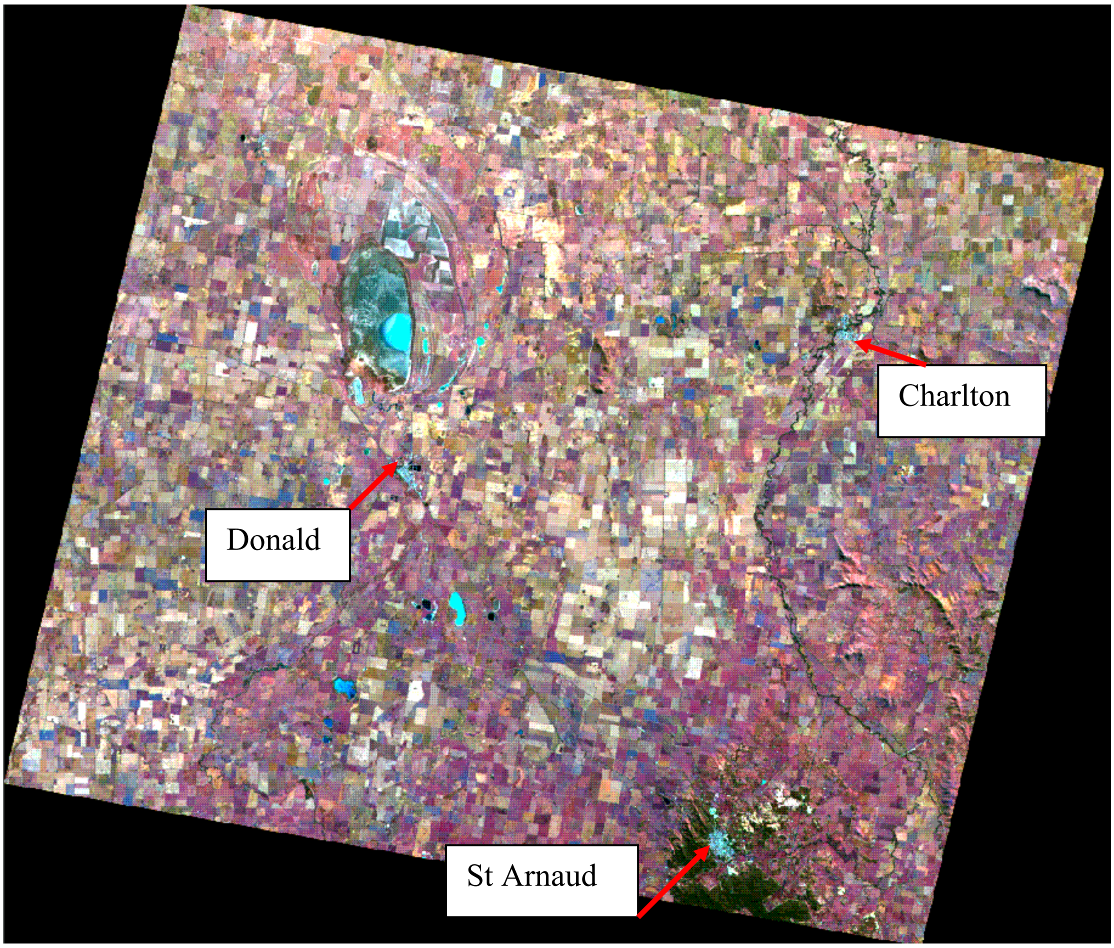


Figure 3.2: SPOT 4 satellite image from 30/06/1998 of the Gooroc area

3.3.1 Climate in the Gooroc area

Precipitation

The test site was within the semi-arid zone of southern Australia in the State of Victoria and had in general moderately dry hot summers and moderately wet mild to cool winters. On average, the area received annually a total of 407.2 mm in the North-West (Donald) to 430.8 mm (Charlton) in the West to 506.2 mm in the South-East (St. Arnaud, Fig. 3.3) (BOM, 2005). Usually 60% of the rainfall occurred between May and October.

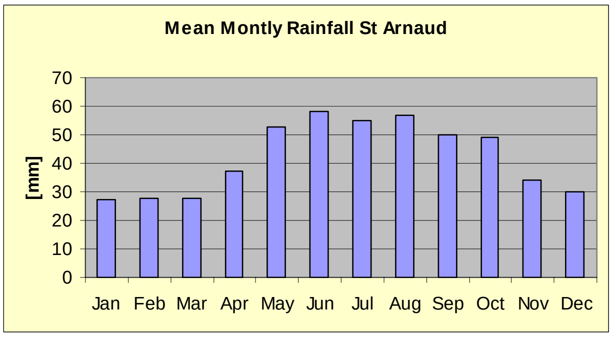


Figure 3.3: Average monthly precipitation (data: BOM 2005)

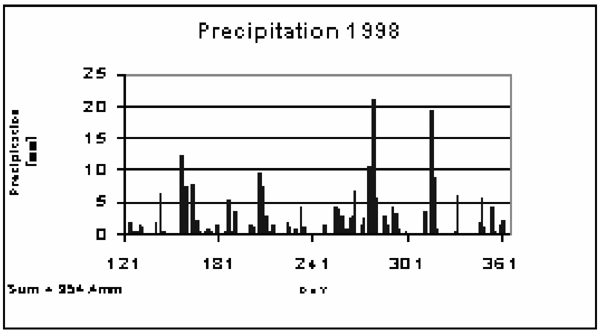


Figure 3.4: Precipitation in the 1998 crop season (from Aigner, 1999)

In comparison, Figure 3.4 shows the mean rainfall in the Eastern Wimmera as measured and interpolated at 7 meteorological stations throughout the growing season 1998 (May to December) (Aigner, 1999). In 1998 the sum of rainfall was slightly higher than in the previous years, with a reasonably homogeneous distribution. Short periods without rain occurred around Day of Year (DOY) 240 and DOY 300.

Temperature

Temperatures in the Wimmera are in the temperate climate zone, with a maximal mean daily temperature of about 30°C and a minimal mean daily temperature of ca. 4°C in July.

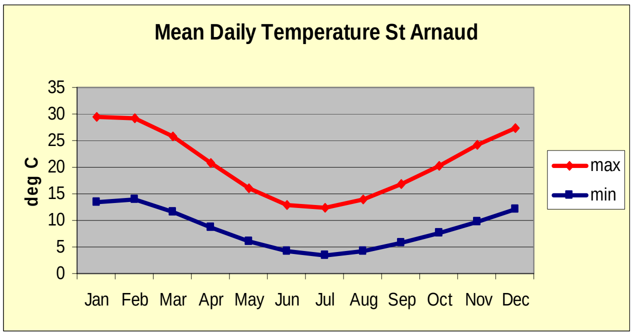


Figure 3.5: Average daily temperature (statistics data from BOM 2005)

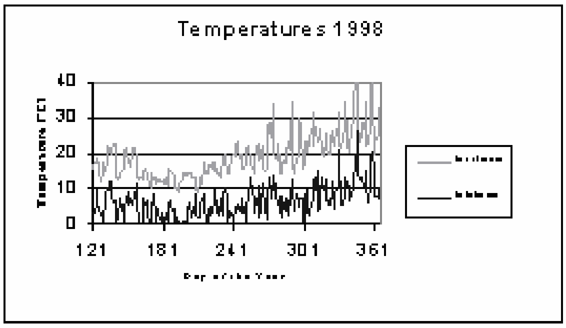


Figure 3.6: Daily min. and max. temperatures in the 1998 crop season (from Aigner, 1999)

Figure 3.5 shows the average monthly minimum and maximum temperature (averaged from 1880- 2004; BOM, 2005), while Figure 3.6 illustrates the daily maximum and minimum temperature values for the 1998 crop season (May – December) (averaged from the stations Donald, Warracknabeal and Longeroong in the Eastern Wimmera; Aigner, 1999).

Frost

Light frosts occur when the air temperature drops below 2.2°C, while severe frosts are commonly associated with 0°C or lower. Several frosts may occur in the test site during the cooler month (May – October). Although winter frosts are more common, frosts during spring may constitute a serious hazard to crops, causing damage (Figure 3.7). Several days of frost occurred in 1998 (Figure 3.6); especially the late frost days around DOY 300 (October, 27th) heavily affected crops.

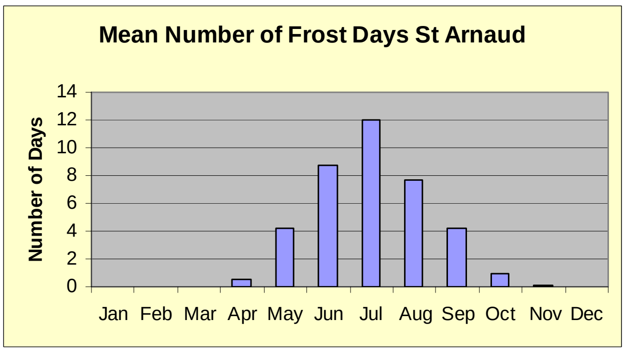


Figure 3.7: Monthly average number of frost days per month with temperatures below 2°C (statistics data from BOM, 2005)

In summary, the 1998 weather in the Gooroc area affected cereals due to the drought around DOY 240. Canola was not stressed by the dry weather during that stage. Frosts during the flowering and grain filling period significantly diminished the yield results of all crops. Dry unsteady development and unfavourable conditions throughout the growing season lead to very low yield for cereals, and low yield for canola.

3.3.2 Geology

Some of the oldest rocks in Victoria occur in the St Arnaud region. They are Cambrian to early Ordovician marine sediments (mudstones, siltstones and shales). Subsequent uplifting along fault lines resulted in the sea retreating to the east and marine sedimentation concluded in the St Arnaud region (Imhoff, 1996). These uplifted and folded sediments were then eroded in the next era. The Gooroc area lies within the Murray Basin (sedimentary formed in the tertiary period). As global sea levels rose, the basin was flooded by the sea and formed the "Murravian Gulf", a shallow sea which covered the Wimmera and Mallee region and extended into NSW (Imhoff, 1996). In the late Tertiary, the sea retreated in numerous stages and resulted in the formation of multiple coastal ridges and left behind sandy coastal plains. The up most Tertiary deposits are referred to as the "Parilla Sandstone" (Imhoff, 1996). The upper few metres was often cemented by iron oxides during lateritization in a more tropical tertiary climate. Outcrops of ferruginised Parilla Sandstone can be found today on the slopes of a lunette south of Lake Bulloke. Much of the Tertiary sandstone has since been removed or covered by aeolian, alluvial and lacustrine deposits during the Quarterny, with major climatic oscillations (ice ages). In the Gooroc area the sandstone has been largely covered with Quarterny alluvial and aeolian calcareous red, brown and grey clay deposits which are referred to as the "Shepparton formation" (Imhoff, 1996). These deposits are estimated to be 5-10 metres thick (Imhoff, 1996). West of Gooroc, in the Donald area lie largely Quarterny aeolian deposits which form dunes and swales systems. These deposits are referred to as "Woorinen Formation" and occur extensively in the Mallee region (Imhoff, 1996; Douglas and Ferguson, 1988; Ryan, 1993).

3.3.3 Soils

The test site is situated on the western side of the mid-section of the Avoca River catchment area, on the edge of the Wimmera plains. The plains have at various times been inundated by sea, with deposition of marine sands as a result, that in places reach thicknesses of three kilometres (Anon, 1993). Calcareous wind-borne dust, blown from the Mallee to the west, covers these plains contributing to current soil resource. These soils consist of several soil associations, depending on underlying parent material (Postlethwaite, 1998).

The soils found in the Gooroc area are mainly red, brown and grey clays which are Vertosols and Sodosols (McDonald et al. 1990). Vertosols are soils with distinct shrink and swell properties that display strong cracks when dry and have slickensides and/or lenticular structural aggregates at depth (GRDC, 2005). Many Vertosols exhibit gilgai micro relief. The cracks are at least 5 mm wide and extend upward to the surface or to the base of any plough layer, forming a self-mulching horizon (GRDC, 2005). The cracks may not always be visible on the surface, but this micro-relief can result in variable crop growth across the paddock (Imhoff, 1996). Vertosols are subject to detrimental structural deformations when under cultivation, such as water logging, clay pan formation and compaction (Ellis and Mellor, 1995). Vertosols are used for extensive dryland agriculture where rainfall is adequate and for irrigated agriculture. Problems of water entry are usually related to tillage practices and adverse soil physical conditions at least partly induced by high sodium in the upper part of many profiles. Vertosols are also known as black earths; grey, brown and red clays; cracking clays (GRDC, 2005).

Sodosols are duplex soils and display a clear or abrupt textural change between the A and the sodic B horizon. The B horizon is not strongly acid and may also be saline. The soil genesis of sodosoils has been associated with low annual rainfall (<900mm) (Sumner and Naidu, 1998). More than 60% of the 20 million ha of cropping soils in Australia are sodic and farming practices on these soils are mainly performed under dryland conditions. More than 80% of sodic soils in Australia have dense clay subsoils with high sodicity and alkaline pH (>8.5). The actual yield of grains in sodic soils is often less than half of the potential yield expected on the basis of climate, because of subsoil limitations such as salinity, sodicity, alkalinity, nutrient deficiencies and toxicities due to boron, carbonate and aluminate. Sodic subsoils also have very low organic matter and biological activity (Rengasamy, 2002).

The dominant soil types in the test site are Murra Warra, Kalkee 2 and Callawadda soil types (Figure 3.8). The paddocks on the western slopes of Mt. Jeffcott are dominated by red cracking Murra Warra clays. These gently undulating rises were formed by sedimentary rock and are overlain by a layer of wind blown clay (Anon, 1992). The rises extend further south, which are also Murra Warra soil types, although they are mainly brown cracking clays. Kalkee 2 soil type is similar to the Wimmera sedimentary rises. However, they are overlain by Parilla Sands, and are formed in north-west trending ridges. They are commonly known as “marine plains” and consist of predominately cracking grey and brown clays (Ug. 5.1 to 5.3) with cracking red areas. Callawadda soil type (Dr 2.13) are associated with a water-courses; paddocks are not productive in wet years and considered better suited to grazing than cropping. However, in cracking brown clay, Callawadda soil type can be managed by construction of livestock and domestic water channels. Paddocks on river flats along the Avoca River are also Callawadda soil type (Dr 2.13) (Postlethwaite, 1998). Figure 3.8 shows a subset of Badawy’s soil map (1983) for the Gooroc area. The marked fields were some of the ground sampling sites used in the study.

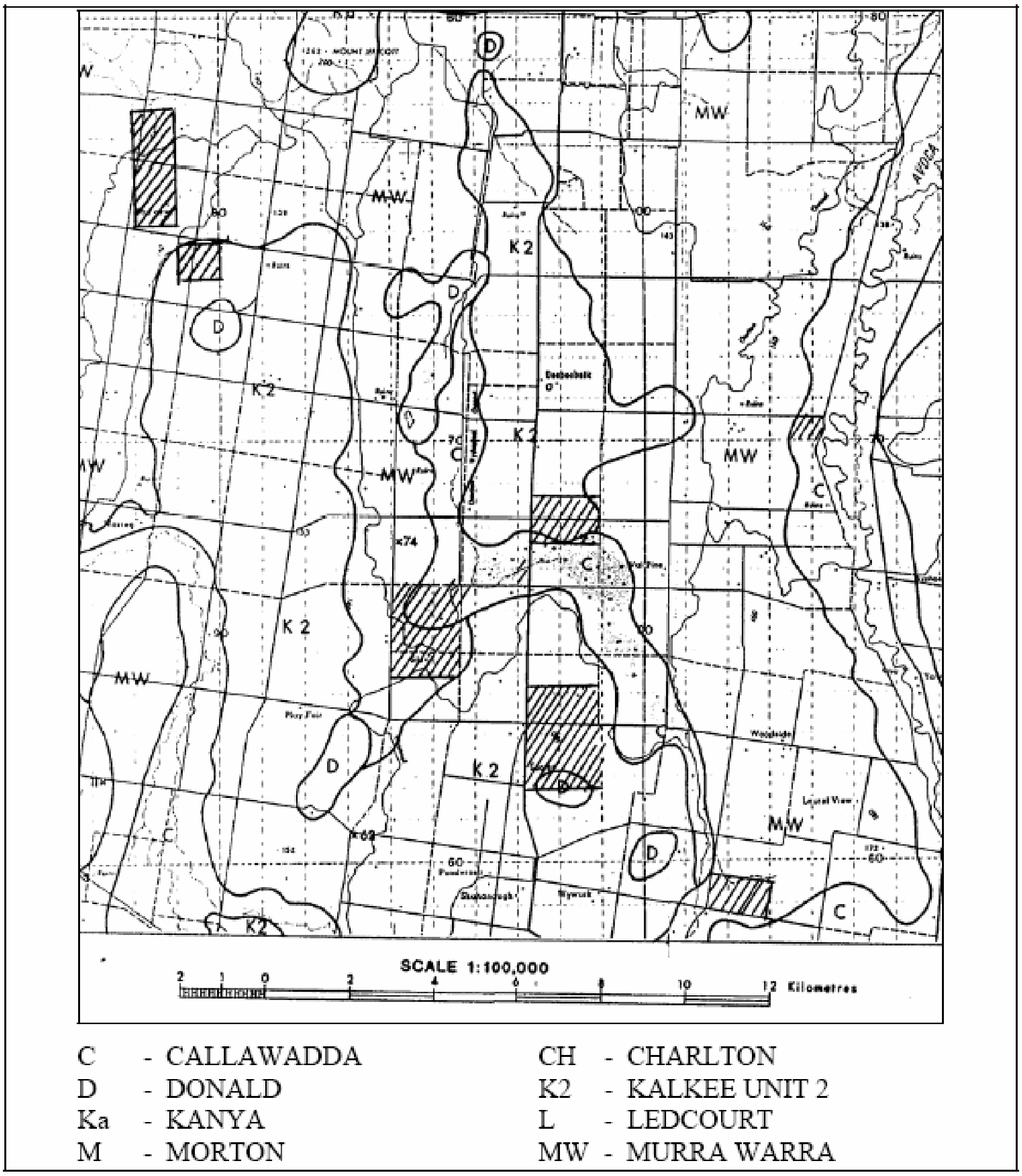
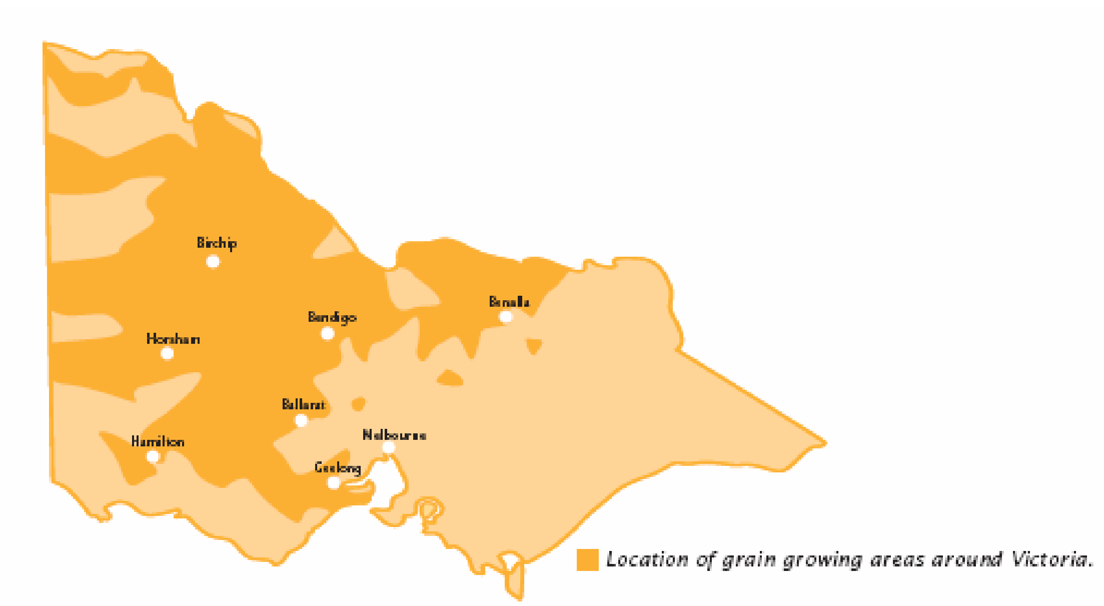


Figure 3.8: Soils of the Gooroc study area (from Postlethwaite, 1998; source Badawy, 1983)

3.4 Grains industry in Victoria

Victoria is one of the smallest states of Australia by area. However, Victoria's rich soils and temperate climate make it a very productive agricultural area, generating one quarter of Australia's food exports. Victoria employs approximately 75,000 people in the agriculture sector (ABS Cat. 6291.0.55.001) and in 2002/03 produced $A6.1 billion worth of food (ABS Cat. 7121.0) There are 2,639 grain growing enterprises and 3,199 mixed farms with grain and sheep/cattle farming (ABS 7121.0; DPI, 2005).

The Victorian grains industry currently accounts for approximately 10% of Australia's national grain production with the majority of this production comprising wheat and barley (ABS 7121.0; DPI, 2005).



Orange coloured areas represent grain growing areas while peach coloured areas have other land use.

Figure 3.9: Map of grain growing areas in Victoria (from DPI, 2005)

Figure 3.9 shows the location of grain growing areas in Victoria. In the past, the grains industry was predominantly based in north west Victoria where climate conditions were most suited for production of dryland (non-irrigated) crops. However, in recent years the production of high quality grains and oilseeds has rapidly expanded into the cooler, southern regions of Victoria (DPI, 2005).

Victorian cropping farms generally grow a mix of cereals, pulses and oilseeds in order to maintain soil fertility, reduce soil borne diseases and provide a good income mix for farmers (DPI, 2005). Crops were rotated annually and in the past research by government and industry had insured that improved crop varieties were regularly developed and released. Victorian grain growers have a reputation for producing grains of a consistently high quality (DPI, 2005). This was due to large farm operations producing large homogeneous volumes of grain. Furthermore suitable soils, a temperate climate and modern storage and transport facilities assisted the high produce quality (DPI, 2005).

Surplus Victorian broad acre grain crops were grown for export and were important trading commodities. The major grains produced for export were wheat, barley, canola, field peas, lentils, faba beans, chickpeas, lupines, oats and triticale. Figure 3.10 shows the value of Victorian grain exports for various produce (DPI, 2005).

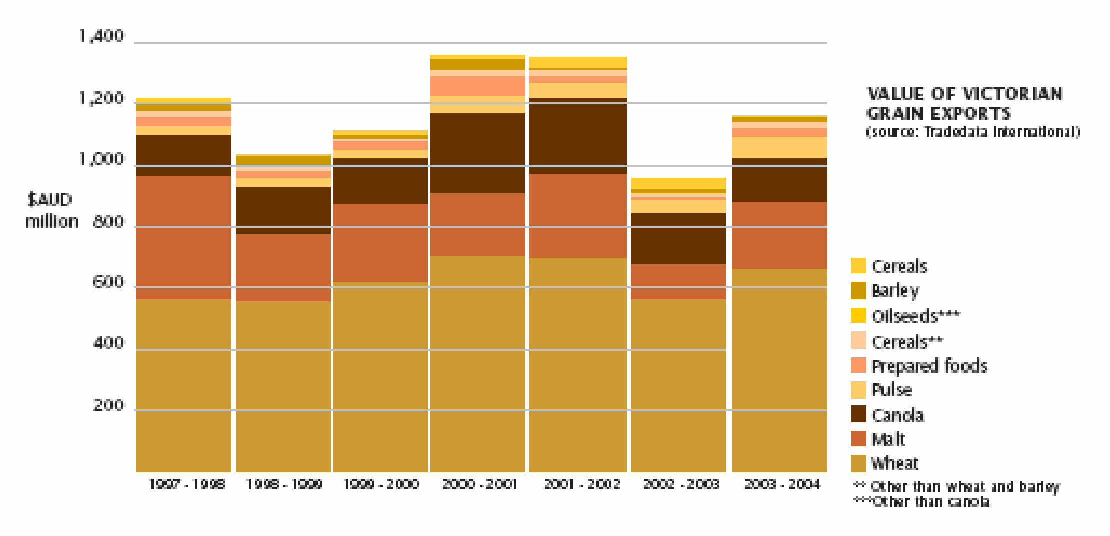


Figure 3.10: Export value of various Victorian grains from 1997- 2004 (from DPI, 2005)

The major markets for Victorian grain were the Middle East and Asia; seven out of the top 10 grain export destinations were in the Asian region (DPI, 2005).

North Asia and South East Asian countries were important buyers for noodle quality wheat. Japan was the number one market for Victorian grain in 2003/04 valued at $A122 million, an increase of 45% or $A38 million from 2002/03 (DPI, 2005). This

was followed by Vietnam ($A42 million), South Korea ($A34 million) and New Zealand ($A27 million). China also imported Victorian malting barley (DPI, 2005).
A large wheat markets also existed in the Indian subcontinent. Furthermore, India was a significant customer for pulses (DPI, 2005). The Middle Eastern export destinations included Iraq and Iran for wheat, Egypt for lentils and wheat and Saudi Arabia for feed barley (DPI, 2005).

3.5 Grain crops under investigation

The crop types under investigation in this study were barley, canola, chickpeas, lentils and wheat. These five crops were chosen as they were economically important south east Australian grain crops and were cultivated by the farmers participating in the ALMIS study. Following, each crop is described in respect to its origins, uses, cropping information and productivity figures.

3.5.1 Barley (*Hordeum vulgare*)

Scientific classification

Kingdom: *Plantae*; Division: *Magnoliophyta*; Class: *Liliopsida*; Order: *Poales*; Family: *Poaceae*; Genus: *Hordeum*; Species: *H. vulgare*

Barley crop in flower

Barley flower

Barley seeds

Figure 3.11: Photographs of barley field, flower and seeds (from DPI, 2000)

Figure 3.11 shows that barley looks very similar in the paddock to wheat (Fig. 3.24). It also has awns but is lighter yellow-green in colour. During senescence, the awns turn yellow and the heads begin bends below the head (nodding) (DPI, 2005).

History

Cultivated barley descended from wild barley (*Hordeum spontaneum*), which is still present in the Middle East. Both luder forms were diploid (2n=14 chromosomes); all variants of barley produced viable seed when crossed and are thus considered to belong to one and the same species (Wikipedia, 2005). Compared to domesticated barley, wild barley had brittle rachis that are conductive to self-propagation. The oldest finds of barley were made in Epi-Paleolithic sites in the Levant (Natufian) (Wikipedia, 2005). The first domesticated barley has been found in the aceramic neolithic layers of Tell Abu Hureyra in Syria (Wikipedia, 2005). The domestication of barley occurred contemporaneous to that of wheat (Wikipedia, 2005). In history barley was seen as an ancient and central gift of the earth and had ritual significance. Reference to barley can be found in the Homeric hymn to Demeter (Greek goddess of agriculture). Since the earliest stages of the Eleusinian mysteries, initiates prepared themselves with Kykeon, also called "Barley-mother" (a mixed drink from barley and herbs); according to Pliny's Natural History (AD 77), Greek practice was to dry the barley grouts and roast them prior to preparing porridge; this produced malt that soon fermented and became slightly alcoholic (Wikipedia, 2005).

Use

The majority of Wimmera barley is of malting quality and is used for beer making. Downgraded grain is important for stock feed (DPI, 2000).

Cropping information

Crop duration

The minimal barley crop duration exceeds 200 days, thus sowing in south east Australia is required before early to mid-June. Long et al. (1998) reported that earlier sowings allowed plants to reach grain filling in a mild environment which favoured starch rather than protein deposition, hence higher yields with lower protein levels were achieved (in Victoria, Malt 1 must have protein levels between 9-11%). Research in NSW supported the concept that early sowing is one of the keys to achieving desirable protein levels.

Plant density

Optimum plant density in most areas was about 120 plants per square meter, equating to a seeding rate of about 70 kg/ha (assuming an average seed weight of 46 mg and an establishment rate of 80 per cent). Barley was highly susceptible to water logging and less tolerant of acid soils than other crops, particularly soil acidity associated with aluminium toxicity. Under those conditions, a higher plant density partially compensated for the lack of tillering (Long et al. 1998).

Sowing depth

The best sowing depth was found to be between 2 cm and 3 cm; the rate of development and tillering was restricted by excessive seeding depth. Seeding too deep resulted in poor early weed competition and the need to delay weed spraying until the seedlings reached a safe development stage (Long et al. 1998).

Fertilizer applications

Testing of barley plants at the 5 leaf stage showed, that crops with high concentrations of phosphorus, nitrogen, manganese and zinc had the highest chance of producing protein less than 11.8 per cent. Nitrogen application needed to be complemented with appropriate rates of phosphorus for the targeted yield, as the maximum benefit from nitrogen application was not achieved without the application of the appropriate rate of phosphorus (Long et al. 1998). Long et al (1998) reported further that the timing of nitrogen application was critical for both quantity and quality of yield. Post sowing applications of nitrogen increased grain protein concentrations, in particular if the application was delayed beyond the 5 leaf stage of development. The influence of late application of nitrogen became more pronounced in dry seasons. Victorian studies had shown that maximum yield responses in dry seasons were achieved by the application of nitrogen at sowing, while maximum yield responses in wet seasons were achieved by splitting the nitrogen applications between pre- and post sowing (Long et al. 1998). In the Wimmera, soil and growing conditions favoured the production of low protein content in cereals. But significant tonnages of Wimmera barley (particularly the variety

Arapiles) failed to meet Malt 1 protein specifications because of protein levels below 9 per cent. Long et al. (1998) concluded that nitrogen management in the Wimmera needed to be improved for the production of premium quality malting barley.

Disease management

Without adequate roots and/or leaves, the plants were not able to use available nutrition and moisture to meet yield targets. It was therefore necessary to control root and foliar diseases (Long et al. 1998). The absence of a Cereal Cyst Nematode (CCN) resistant malting varieties required growers to closely monitor levels of CCN in the crop rotation, both before and after growing a malting variety (Long et al. 1998). While barley was more tolerant of CCN than wheat, serious yield losses occurred in barley in the presence of high levels of the nematode. Take-all (caused by the root-infecting fungus *Gaeumannomyces graminis*) and Rhizoctonia (caused by root rotting fungus *Rhizoctonia solani*) were also serious diseases of barley (Long et al. 1998). Crop rotation strategies and cultivation practices needed to be adopted to control these diseases. When barley followed canola in crop rotation, low root disease incidences and relatively low levels of soil nitrogen were observed (unless the previous canola crop had failed) (Long et al. 1998). A successful combination was also barley following chickpeas or field peas, although soil nitrogen levels needed to be closely monitored in the drier areas and on paddocks without intensive cropping histories. Barley following wheat often resulted in the build-up of root diseases and low yields (Long et al. 1998).

Frost risk

Frost and low protein levels were a risk in the Wimmera. It was identified that for highest quality yield (not necessarily highest quantity yield) with required level of grain protein, and best yield response to nitrogen, sowing in mid-May to mid-June for mid-season varieties (such as Arapiles and Schooner) became a priority (Long et al. 1998). In some years frost damage occurred when sown too early in the Wimmera. Flowering of barley crops needed to be timed to occur during the second and third weeks of October in order to minimize risk of frost damage (Long et al. 1998).

Barley Production

Figure 3.12 shows the location of the main production areas in Australia for winter barley as well as the percentage of production that each State contributes and the crop calendar.

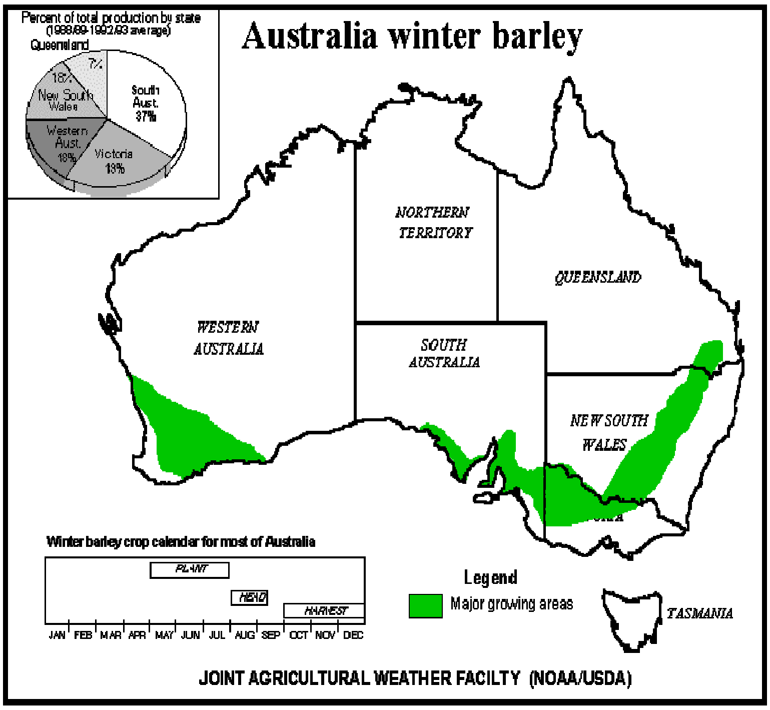


Figure 3.12: Map of Australian winter barley production areas (from WBC, 2005)

The average production of barley in Australia over the last 10 years (1995-2004) was approx. 6,000,000 Mt, with noteworthy good years in 2001 and 2003, and a poor year in 2002 due to severe drought conditions (Figure 3.13). Barley production in 2002 was down 61% from the previous year 2001 (ABARE, 2003). Around 3,000,000 ha were sown to barley in Australia in the last 10 years (Figure 3.14). In 1999, fewer hectares were sown to barley, consequentially affecting production in 1999.

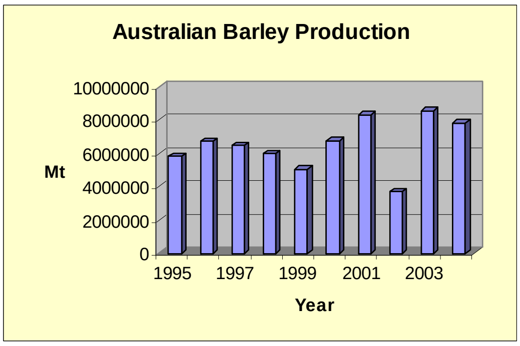


Figure 3.13: Amount of barley production in Australia (from FAO, 2005)

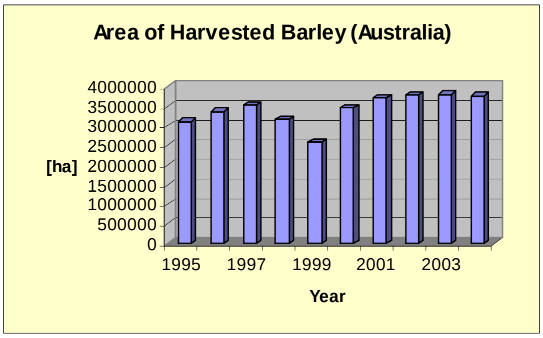


Figure 3.14: Area of barley production in Australia (from FAO, 2005)

3.5.2 Canola (*Brassica napus*)

Scientific classification

Kingdom: *Plantae*; Division: *Magnoliophyta*; Class: *Magnoliopsida*; Order: *Brassicales*; Family: *Brassicaceae*; Genus: *Brassica*; Species: *B. napus*.

Canola crop in flower

flower

Canola seeds

Figure 3.15: Photographs of canola field, flower and seeds (from DPI, 2000)

Figure 3.15 shows a canola field in with its distinct yellow flowers, a single flower and the seeds.

History

The history of canola oil began with the rapeseed plant, a member of the mustard family. The rape plant is grown both as feed for livestock and birdfeed. For 4,000 years, the oil from the rapeseed was used in China and India for cooking and as lamp oil (CRB, 2005). Rapeseed oil was produced in the 19th century as a source of a lubricant for steam engines. During World War II, rapeseed oil was used as a marine and industrial lubricant (CRB, 2005). After the war, the market for rapeseed oil plummeted. Rapeseed growers needed other uses for their crop, and that stimulated the research that led to the development of canola (CRB, 2005). In 1974, Canadian plant breeders from the University of Manitoba produced canola by genetically altering rapeseed. The original oil had a bitter taste due to high levels of glucosilolates (mustard flavour). The oil was also shown to cause heart lesions due to high levels of erucic acid (CRB, 2005). Canola has been bred to reduce the amount of glucosinolates and erucic acid, yielding a palatable oil. Canola stands for CANadian Oil Low Acid (Wikipedia, 2005).

Use

Canola is grown for its seeds which are crushed for the oil used in margarine, cooking, salad oils and edible oil blends (NRE, 2000). Each canola seed contains approximately 40% oil. The properties of the oil, second only to olive oil in the proportion of mono-unsaturated fatty acids, fits with the current view that human health is better served by increasing the intake of mono and poly unsaturated fats in place of animal fats (NRE, 2000).

After the oil is extracted, the by-product is a protein rich meal that is used by the intensive livestock industries (NRE, 2000). The meal has a very low content of the glucosinolates responsible for metabolism disruption in cattle and pigs. Rapeseed leaves are also edible, similar to those of the related kale. Some varieties of rapeseed are sold as greens, primarily in Asian groceries (Wikipedia, 2005). Rapeseed is a heavy nectar producer, and honeybees produce a light coloured, but peppery honey from it. Rapeseed growers contract with beekeepers for the pollination of the crop (Wikipedia, 2005).

Cropping Information

Crop rotation

Canola was found to be a profitable crop in its own right as well as working favourably in crop rotation with cereals or pulses. Across the southern Mallee, Wimmera and mid-north canola yields of 2.5 tones /ha were common (NRE, 2000). Yields of 4 tones /ha were achieved by some farmers in better years (NRE, 2000). Cereal yields after canola were usually enhanced due to diseases reduction when an unrelated crop type (canola) was interspersed between cereals. Canola was well suited for a crop sequence on wheat/sheep farms in the 450 mm – 550 mm rainfall zones (NRE, 2000).

Fertilizers

Nitrogen requirements were dependant on canola's position in the crop rotation. When grown later in the crop sequence (for example after a cereal crop) substantially more nitrogen (100 kg/ha) was required than when grown as a first crop after clover or medic pasture (NRE, 2000). Furthermore phosphorus fertilizers were needed. Applications at sowing and in some situations topdressing of urea in late winter were commonly necessary (NRE, 2000).

Insect, disease and weed control

Canola seedlings were vulnerable to red legged earth mite. Some degree of mite control was obligatory. As canola crop growth was initially slow, pre-emergence herbicides were needed to ensure that the seedlings were not smothered by weeds. Once past the seedling stage vigorous crop growth restricted weed development; the dense crop canopy smothered most surviving weeds. From the elongation stage up until harvest, insect pests were also only sporadic issues (NRE, 2000).

Canola specific crop management

For grain farmers, the essentials of wheat and canola were the same. The crop was sown in late autumn or early winter into moist soil. There was however two major differences between the traditional crops and canola which required modified management. The first was seed size. Canola had a very small seed which meant that sowing depth had to be well controlled. It was observed that alternate wetting and drying of the seed on the soil surface caused patchy germination; hence it was recommended that the seed needed to be lightly covered with soil during sowing, which ensured more protection from drying out after germination (NRE, 2000). The second difference was the need to windrow the crop to minimize seed loss (NRE, 2000). A ripe standing crop of canola was vulnerable to wind damage. Swaying stems brought the brittle pods in contact which caused shatter and seed loss. Windrowing or swathing involved cutting the crop 8-10 days before the seed was fully mature. The swathe lay in horizontal bundles 10cm - 20cm off the ground supported on the cut stems. Ripening of the pods and seeds continued with less risk of movement caused by strong winds. When judged to be ripe the swathe was picked up by the harvester (NRE, 2000).

Canola Production

Australian canola production (Figure 3.16) and area (Figure 3.17) had a wide annual range in the last 10 years, increasing to a strong peak in 1999 (2,500,000 Mt on 2,000,000 ha) and levelling at approx.1,500,000 Mt with a trough in 2002 due to severe drought conditions (production in 2002 was reduced by 65% from the previous year 2001; ABARE, 2003).

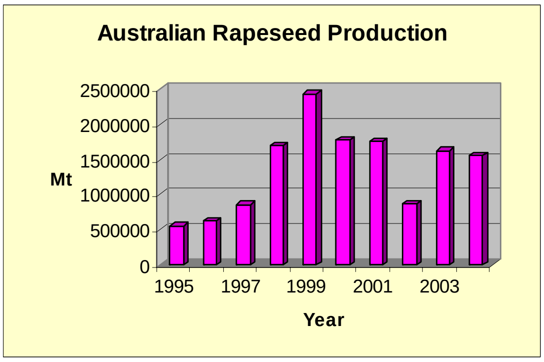


Figure 3.16: Amount of canola production in Australia (from FAO, 2005)

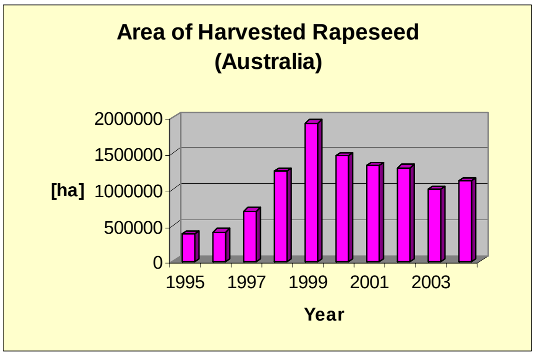


Figure 3.17: Area of canola production in Australia (from FAO, 2005)

3.5.3 Chickpeas (*Cicer arietinum*)

Scientific classification

Kingdom: *Plantae*; Division: *Magnoliophyta*; Class: *Magnoliopsida*; Order: *Fabales*; Family: *Fabaceae*; Genus: *Cicer*; Species *C. arietinum*

Chickpea crop in flower   Chickpea flower   Chickpea seeds

Figure 3.18: Photographs of chickpea field, flower and seeds (from DPI, 2000)

History

The oldest finds of domesticated chickpeas were made in the aceramic levels of Jericho and Cayönü in Turkey and the pottery Neolithic in Hacilar (Turkey). They were found in the late Neolithic (at ca. 3500 BC) in Thessaly, at Kasptanas, Lerna and Dimini (Wikipedia, 2005). In the southern French cave of L'Abeurador Dept. Aude chickpeas have been found in Mesolithic layers, dated with the radiocarbon method to 6790+90 BC (Wikipedia, 2005). By the Bronze Age they were known in Italy and Greece. In classical Greece, chickpeas were called erébinthos, and eaten as staple and dessert (raw when young). Carbonized chickpeas have been found at the Roman legionary fort at Neuss (Novaesium), Germany in layers of the 1st century AD. The Romans knew several varieties, for example venus-, ram- and punic chickpeas. The Roman gourmet Apices gave several recipes for chickpeas. They were eaten as broth and roasted as snacks (Wikipedia, 2005). Chickpea were mentioned in Charlemagne's Capitulare de villis (ca. 800 AD) as cicer italicum, and were grown in each imperial demesne (Wikipedia, 2005). Albertus Magnus knew three varieties, red, white and black.

Chickpeas were grown in some areas of Germany up to World War I; afterwards they were used as Ersatz-Kaffee (Wikipedia, 2005).

Use

Chickpeas can be eaten in salads, cooked in stews, ground into a flour called gram flour (also known as besan, and used in Indian cuisine), ground and shaped in balls and fried as falafel, cooked and ground into a paste called hummus, or roasted and spiced and eaten as a snack. The plant can also be used as a green vegetable (Wikipedia, 2005).

Cropping information

Crop rotation

Chickpea being a legume is a nitrogen-fixing plant. It was found to be a "break" crop against take-all disease of cereals (*Gaeumannomyces graminis*) and Cereal Cyst Nematode (*Heterodera major*) and to enhance cereal yield. The nutritional quality of the stubble is better than cereal stubble due to the protein content of the grain on the ground and the digestibility of the straw (Robinson, 1994).

Optimum climatic growth conditions

Optimum growth temperature was 20°C. Chickpeas tolerated higher temperatures at seeding than peas and lupines. Cool and wet environment increased risk of infection with foliar diseases. The frost tolerance of chickpeas was found similar to the tolerance of wheat. Chickpeas required an average annual rainfall of 375 mm for the Desi variety (smaller seed) and 450 mm for the Kabuli type (larger seed) (Robinson, 1994).

Crop treatments

Robinson (1994) recommended inoculation with chickpea inoculum prior to seeding on all soil types. Seed from a healthy crop was preferred to using seed dressing to control seed borne diseases, as seed dressing affected the performance of the Group N inoculum. Seed needed to be sown as soon as possible after inoculation for nodulation to be effective. Fertilizer requirements were 40 kg/ha of single superphosphate, (or its phosphorus equivalent) for every tone of grain per hectare (Robinson, 1994).

Harvest

The average yield was 1.3 t/ha with yields ranging from 0.5 to 2.5 t/ha. As pods fall at maturity, harvesting needed to occur promptly; however no windrowing was required. The pods were held in the canopy and therefore conventional grain harvesters could be used to harvest chickpeas. (Robinson, 1994)

Chickpea Production

Australia was an important exporter of chickpeas to the Middle East. However in recent years production has greatly suffered due to problems with *Ascochyta* blight and Grey mould destroying the crop (Bretag et al., 2005); Treatment is now mandatory if chickpeas are grown and adds to the production cost (Bretag et al., 2005); hence farmers prefer to plant other lower risk and cost crops (Figure 3.20, area is recessing). Furthermore, Chickpeas production in 2002 was affected by severe drought (Figure 3.19).

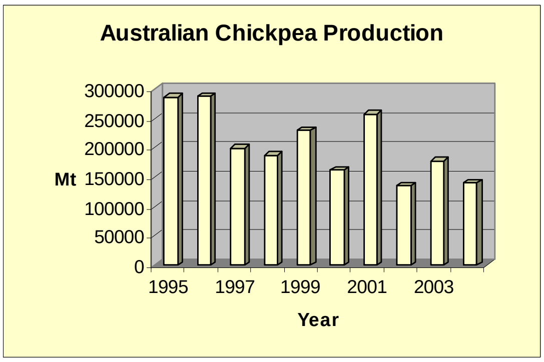


Figure 3.19: Amount of chickpea production in Australia (from FAO, 2005)

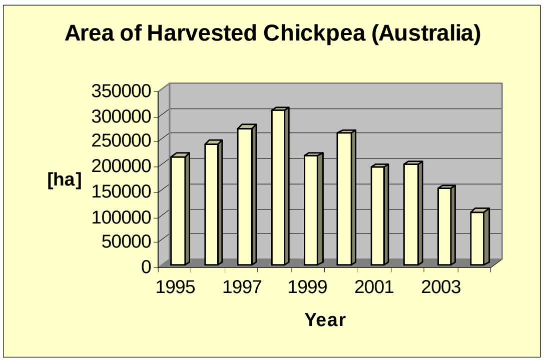


Figure 3.20: Area of chickpea production in Australia (from FAO, 2005)

3.5.4 Lentils (*Lens culinaris Medikus*)

Scientific classification

Kingdom: *Plantae*; Division: *Magnoliophyta*; Class: *Magnoliopsida*; Order: *Fabales*; Family: *Fabaceae*; Subfamily: *Faboideae*; Tribe: *Vicieae*; Genus: *Lens*; Species: *culinaris*

Lentil crop in flower   Lentil flower   Lentil seeds

Figure 3.21: Photographs of lentil field, flower and seeds (from DPI, 2000)

History

The earliest archaeological finds of lentils were from the Paleolithic and Mesolithic layers of the Franchthi Cave in Greece (13,000 to 9,500 years ago); furthermore discoveries were made from the end-Mesolithic at Mureybit and Tell Abu Hureya in Syria, and from about 8000 B.C. in the Jericho area of Palestine (Wright, 2001). Other remains came from Cayönü, Turkey dated at 6700 B.C. and many other sites in the Middle and Near East. Lentils were an important crop in ancient times and the size of the seeds slowly increased since classical times. Lentils were domesticated along with einkorn and emmer wheat, barley, pea, and flax during the Old World agricultural revolution in prehistoric times and spread with Neolithic agriculture to Greece and Bulgaria (Wright, 2001). Lentils were spread further, together with wheat and barley, into the Bronze Age agriculture of the Near East and Mediterranean. Lentils played a role in Jewish culture as known from the story of Esau who gave up his birthright for a dish of lentils (Genesis 25: 30-34). The ancient Greeks enjoyed lentils in soups and made lentil bread. Pliny described lentil crop growth and lentil varieties. He mentioned its medicinal properties and a variety of recipes for lentil preparation as remedies

(Wright, 2001). Both Roman writers Juvenal and Martial described a lentil dish eaten by the poor called conchis in which lentils were cooked with the pods (Wright, 2001).

Use

A variety of lentils exist with colours that range from yellow to red-orange to green, brown or even black. Lentils are generally sold as dry seeds both in large and small-seeded varieties (Wikipedia, 2005). The lens-shaped lentil seeds have a short cooking time and a distinctive earthy flavor. In the West, lentils are used to prepare an inexpensive and nutritious soup (Wikipedia, 2005). Lentils are used throughout the Mediterranean regions and the Middle East. In India, lentils are mostly found in split form. Stripped of their outer skin, split lentils are usually bright orange, green or brown in colour. The thick, spicy stew prepared from lentil also known as Dal (Wikipedia, 2005).

Cropping information:

In the Wimmera both red (split) and green (whole) lentils are grown.

Crop schedule

Lentils need to be planted in the correct time window. Early lentil plantings ran the risk of being frosted, were prone to infection with Botrytis grey mould (*Botrytis cinerea*) or grew excessively rank (Lucy, 2002). Late planted crops were very short and difficult to harvest. The crops commenced flowering approximately 100-120 days after a late May-June planting (Lucy, 2002). Late flowering varieties were approximately 15-20 days later flowering than early maturing types (Lucy, 2002). Lentils were flowering profusely over a prolonged period, and it was not uncommon to find tiny white and blue flowers, green pods, and mature prods on the plant at the same time (Lucy, 2002).

Crop treatments

For plant nutrition, phosphorus and zinc requirements were similar to the other grain legumes. Lentils were extremely sensitive to iron deficiency and often foliar sprays were required. Lentils had slow early growth and competed poorly with weeds.

Therefore paddocks with a severe broadleaf weed problem needed to be avoided (Lucy 2002).

Harvest

The crops were considered to be at an optimum stage for desiccation when 90% of the pods were golden-brown. Timing was critical as lentils were predisposed to both shattering and lodging. Crops were usually very short (15-40 cm) with the pods born throughout the plant (Lucy, 2002). This usually required the crop to be cut very close to ground level. Floating cutter bars and flat, level paddocks were considered essential prerequisites for growing lentils. All but the shortest crops lodged at maturity hence crop lifters were required. Careful adjustment of the header was required to avoid cracked grain (Lucy, 2002). In the Wimmera crop yield was 0.5 to 1.5 t/ha (Lucy, 2002).

Lentil Production

Overall, the area of lentil production has steadily increased over the last 10 years (Figure 3.23); a production peak was reached in 2001, however the year following the drought had a dramatic effect on the 2002 lentil harvest (Figure 3.22).

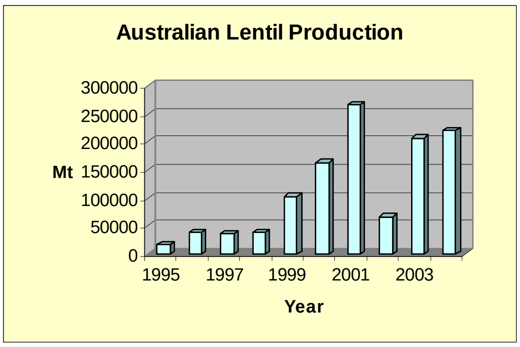


Figure 3.22: Amount of lentil production in Australia (from FAO, 2005)

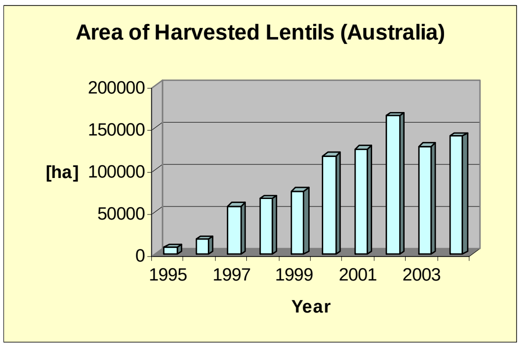


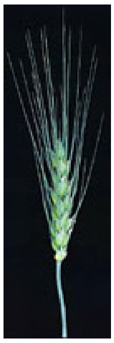
Figure 3.23: Area of lentil production in Australia (from FAO, 2005)

3.5.5 Wheat (*Triticum spp*)

Scientific classification

Kingdom: *Plantae*; Division: *Magnoliophyta*; Class: *Liliopsida*; Order: *Poales*; Family: *Poaceae*; Genus: *Triticum*; Species: *T. aestivum, T. aethiopicum, T. araraticum, T. boeoticum ,T. carthlicum, T. compactum, T. dicoccon, T. durum, T. ispahanicum, T. karamyschevii, T. militinae, T. monococcum, T. polonicum, T. spelta, T. timopheevii, T. trunciale, T. turanicum, T. turgidum, T. urartu, T. vavilovii, T. zhukovskyi*

Wheat crop in flower



flower

Wheat seeds

Figure 3.24: Photographs of wheat field, flower and seeds (from DPI, 2000)

History: Domestic wheat originated in southwest Asia. The oldest archaeological evidence for wheat cultivation came from Syria, Jordan, Turkey, and Iraq (Wikipedia, 2005). The wheats known today are cereals that evolved in the Middle East through repeated hybridisations of *Triticum* spp. with members of a closely related grass genus, *Aegilops*. The process which began some ten thousand years ago involved the following major steps. Wild einkorn *T. boeoticum* is considered to have crossed spontaneously with *Aegilops speltoides* to produce Wild Emmer *T. dicoccoides*; further hybridisations with another *Aegilops*, *A. squarrosa*, gave rise to Spelt, Emmer *T. dicoccum* and early forms of Durum Wheat; Bread Wheat finally evolved when cultivated Emmer re-crossed with *A. squarrosa* in the southern Caspian plains, resulting in a plant with seeds that were larger, but could not sow themselves on the wind (domestication). While this plant could not have succeeded in the wild, it produced more food for humans, and was cultivated. During the expanding geographical range of wheat cultivation, bread was produced as early as 6000 B.C. (Wroot and Pickersgill, 2001).

Emmer

Emmer was a low yielding, tall (2m) awned wheat with small grains and no husk. Emmer is closely related to the modern durum wheat used for pasta, and dates from approximately 7000 BC (Wroot and Pickersgill, 2001). This wheat along with barley has been found from the earliest times in numerous sites of human habitats in Europe and in the near east, including the Pyramids. Domesticated Emmer wheat was the staple cereal of prehistory and the success that changed early agriculture. Emmer is still grown today in remote areas of Turkey and Syria (Wroot and Pickersgill, 2001).

Einkorn

Einkorn has been widely cultivated in Neolithic times and, by the Iron Age, Bread Wheat *T. aestivum* was sustaining populations in much of Europe (Wroot and Pickersgill, 2001). A sub species, Club wheat *T compactum*, was notably grown by Neolithic farmers in Swiss lake side villages (Wroot and Pickersgill, 2001). Identification of the types of crops grown in the Iron Age came from three sources of evidence; carbonized seed, pollen grains and impressions of seed fired into pottery. Einkorn was more resistant to cold, heat, drought, fungoid diseases and bird predation, although its yield was lower than those of emmer, spelt and naked wheat (Wroot and Pickersgill, 2001).

Spelt

Spelt is similar to Emmer but has a tough husk that cannot be removed. Spelt was probably first sown and harvested in the Bronze Age. Spelt has an appalling yield (by weight, not volume) and even when threshed is mostly husk, consequently it is not surprising that Bronze Age man had very worn teeth. Along with Emmer wheat, Spelt was grown extensively in Britain during the late Iron Age and the Roman period. Its modern use is for specialist bread and breakfast cereals (Wroot and Pickersgill, 2001).

Modern wheat

Modern wheat is husk free and with (usually) no awns, it is typically short (less than 1m) and stands well in highly fertile situations (Wroot and Pickersgill, 2001). Wheat quality encompasses the suitability of particular varieties grown in certain environments for the manufacture of particular foods. Harvest segregations for quality are maintained by the Australian Wheat Board and are based on consumer demand. The segregations which account for the majority of the Victorian harvest are Australian Hard 1 (AH, minimum protein 11.5%), Australian Premium White (APW, minimum protein 10.0%) and Australian Standard White (ASW). Special categories of segregations are Australian Noodle (AN, protein range 9.5%-11.5%), Australian Soft 1 (maximum protein 9.5%) and Australian Feed. Varieties that do not meet the specifications of these segregations are received as Australian General Purpose (Hillman and Smith, 1996).

Use

Wheat (*Triticum spp*) is a grass that is cultivated around the world. Globally, it is the second-largest cereal crop behind maize; the third being rice. Wheat grain is a staple food used to make flour, livestock feed and as an ingredient in the brewing of beer. The husk can be separated and ground into bran. Wheat is also planted strictly as a forage crop for livestock and hay (Wikipedia, 2005).

Cropping information

Sewing depth

Most current varieties were derived from so called semi-dwarf lines which have shorter stems and shorter coleoptiles than the former standard varieties. The length of the first shoot (coleoptile) has a bearing on depth of sowing. If a variety was sown deeper than the natural growth extension of the coleoptile then the seedling was delayed or did not emerge. On average, sowing should occur at about 50mm. It was found that shallower sowing risked seed damage from herbicide uptake (Hillman and Smith, 1996).

Crop density

Hillman and Smith, (1996) reported that a crop density of 150-200 plants per square meter was needed to achieve total ground cover and to establish the foundation for maximum yield. This equated to a seeding rate of about 60kg/ha in lower rainfall zones (up to 400mm annual rainfall) and about 75kg/ha in the higher rainfall zones.

Sowing rate was calculated by knowing the seed weight, germination percentage and the required plant density.

Crop treatments

Seed dressings for the control of fungal diseases needed to be applied to all wheat seed prior to sowing. Although major losses from fungal diseases were rare, it was attributed to the routine use of seed treatments. Seed not treated prior to sowing resulted in yield losses as high as 85% (Hillman and Smith, 1996).

Adequate phosphorus was essential for the early growth of wheat. Most Victorian soils were low in phosphorus, and much of the crop requirement needed to be supplied through the application of fertilizers at sowing time (Hillman and Smith, 1996). Paddock history of phosphorus application and crop yields, in conjunction with soil test results determined the rates required. The rule of thumb was a requirement for 3kg/ha of available phosphorus for each tone of wheat anticipated (Hillman and Smith, 1996). Nitrogen availability was equally important. Besides its role in plant growth, the availability of soil nitrogen at grain fill was the key determinant of grain protein. Nitrogen build-up and availability were controlled through the choice of pasture and crop sequences, use of long fallow and tillage methods. The availability of nitrogen in the soil was affected by many factors: soil organic matter, paddock history including fallowing, soil type and moisture content as well as time of year and tillage methods. High yields were a drain on soil nitrogen. Conversely, low yield and summer rain incubated nitrogen which was mobilized for the next crop (Hillman and Smith, 1996).

Wheat Production

In 2004, global wheat production totalled 624 million tones and Australia (22.5 million tones) ranked 7^{th} in the world after: China: (91.3 million tones), India: (72 million tones), United States: (58.8 million tones), Russian Federation: (42.2 million tones), France: (39 million tones) and Germany: (25.3 million tones) (Wikipedia, 2005). However, since Australia's domestic market is small, it was one of the top world exporters of wheat; US was number one; Canada and Australia competed for place two over the last 5 years (USDA, 2002).

Figure 3.25 shows the location of the main production areas in Australia for winter wheat as well as the percentage of production that each State contributes and the crop calendar.

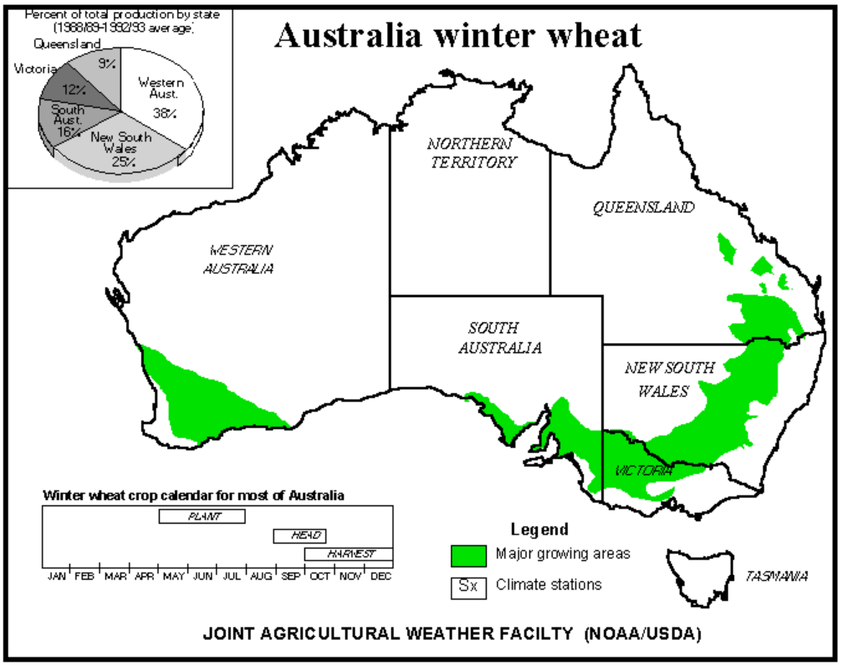


Figure 3.25: Map of Australian winter wheat production areas (from WBC, 2005)

The area planted to wheat in Australia was comparatively steady just above 10,000,000 ha (Figure 3.27). Wheat production (Figure 3.26) had good years in 1999, 2001 and 2003 with about 25,000,000 Mt; major effects of the drought were seen in 2002 on the production figures which were reduced by 62% from the previous year 2001.

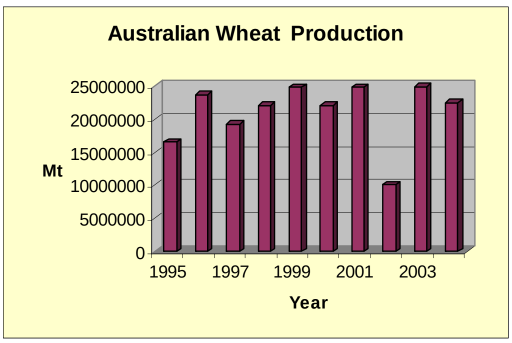


Figure 3.26: Amount of wheat production in Australia (from FAO, 2005)

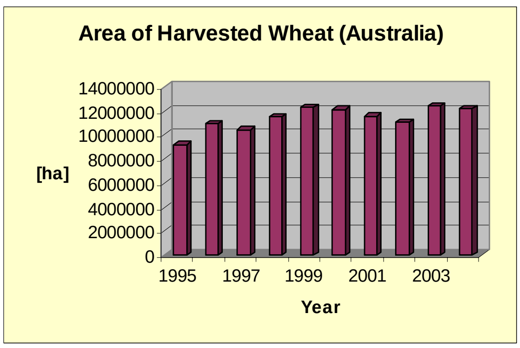


Figure 3.27: Area of wheat production in Australia (from FAO, 2005)

3.6 Conclusions

Agriculture comprises an important socio-economic part of Victoria's industry; it provides employment for approximately 75,000 people and produces more than $6 billion worth of food annually, of which over $1 billion worth of grain is exported almost entirely to Asia. Given the projected global demand for increased Australian exports over the next 20 years, it is important to develop tools for primary producers to increase production in an environmentally friendly manner. The ALMIS prototype crop monitoring concept developed satellite image processing and distribution models to provide information to farmers and land managers from their fields throughout the crop season. A case study was performed in 1998 in a south east Australian test site in the Gooroc area, located between the country towns St Arnaud, Donald and Charlton. The site was chosen for the study as it had an accessible farming community in the heart land of broad acre grain production in Victoria. The location has a temperate, semiarid climate; St Arnaud has an average annual precipitation of approximately 500 mm rainfall, an annual mean maximum temperature of ca. 21˚C and an annual mean minimum temperature of ca. 8˚C. On average there were 39 frost days per year. The predominant soil type were clays (Vertosol and Sodosols), overlaying on Tertiary maritime deposited sandstones. The area is mostly used for dryland agriculture and has large homogeneous fields with an average field size of 115ha. The main grain crops grown in the test site were barley, chickpeas, canola, lentils and wheat. Background on each crop type was given in respect to its history, use, region specific cropping information and production figures. Thus relevant background information was given that would assist the reader to put the next chapters into context.

4. Research design, data and preprocessing methods

4.1 Introduction

The aim of the thesis was to design a concept for a crop monitoring system using remote sensing data for a broad acre grain crop setting. For this concept best industry practice and farmer's needs and comments were to be considered. In this chapter the conceptual research design employed to achieve this goal is described; in addition the data sources and data preprocessing and quality assurance steps are presented.

4.2 Conceptual design

The author's ambition has been to develop a satellite crop monitoring system for farmers. Therefore it was essential to conduct research on remote sensing data of agricultural crops throughout a complete crop growth cycle, to better understand the significant changes occurring in remote sensing data during that time frame. Of great interest was the relationship between the remote sensing data and plant parameters and crop yields under south-east Australian conditions. Hence the experiment was conceptually designed to collect satellite remote sensing data and ground observations/ sampling of crops in the same spatial extend at multiple points in time throughout the 1998 growth cycle and to study the relationship between the remote sensing and ground data. The gained insight was used to develop a concept of a satellite crop monitoring system for farmers and land managers.

The project was designed to study the "typical crop development" throughout the crop growth cycle for the five crop types under investigation: barley, canola, chickpeas, lentils and wheat. Therefore knowledge of the crop type on specific fields was needed; this information was supplied by farmers participating in the ALMIS project. It was investigated how the "typical" spectral properties of these crop fields in south east Australia appeared in the satellite data; these were a reference for further work, acting as a baseline for each crop type. A comparative study was conducted to determine "typical" spectral properties of the same crop types in a different year

(2001). Furthermore it was investigated how well the different crop types could be distinguished from each other at different acquisition dates, using the statistical method of discriminant function analysis.

Ground observations were collected during the 1998 crop cycle by the ALMIS team and included above ground green biomass collection, crop height measurements and soil moisture sampling. After laboratory work, dried above ground green biomass and crop plant water measures could be calculated. It was investigated how the corresponding satellite data and satellite data derived vegetation indices related to the ground samples of a given local sampling point. The Pearson Product Moment coefficient R was calculated at pairwise correlation of the ground observation data for plant height and each of the satellite bands and vegetation indices, respectively. Hereby the data of all dates were combined in one dataset and analysed separately for each crop type. The same procedure was repeated for the other field observations, namely above ground green biomass [g/m^2], dried above ground green biomass [g/m^2], plant water [g/m^2], plant water content [%] and the soil parameters volumetric soil moisture 0-5 cm depth [%] and available soil water 0-100cm depth [mm]. For significant highly related parameters, linear regression equations were retrieved for empirical parameter estimation under south east Australian conditions.

Yield data acquired by precision farming yield monitors at harvest were used to relate yield with the satellite data. Homogeneous areas of interest in the yield maps were extracted and related to spatially corresponding satellite imagery and derived vegetation indices. The Pearson Product Moment coefficient was calculated at pairwise correlations for each single image acquisition date and for accumulated sums. Furthermore a stepwise analysis was conduced on all datasets and standard least square models were derived to investigate if results could be improved.

An early phase prototype crop monitoring system was designed and tested with the involvement of the end users (farmers). It was tested if the processed satellite imagery would assist in finding problem areas in the fields and if the information would result in modified management responses.

Farmers gave feedback in workshops and by questionnaires on the experiment and assisted in the development of an improved concept that considered the end-users requirements. The information gained from the different components of the experiment was then used to develop a concept for an improved satellite crop monitoring system.

Summary of project related tasks

In order to achieve the aim of the thesis, namely to develop a concept for a prototype crop monitoring system, numerous tasks needed to be executed. Table 4.1 gives an overview of the work completed by the author and a reference to where a detailed description can be found. When the research started there was no existing project to join. Therefore set-up tasks associated with the project were included in the task list:

Table 4.1: Task list to conduct ALMIS experiment

Task	Reference
Finding a suitable test site	(Project set-up)
Finding local farmers to cooperate with in the area	(Project set-up)
Gaining support from satellite companies (for imagery)	(Project set-up)
Acquire Images	(Chapter 4)
In situ data collection by farmers and the ALMIS team	(Chapter 4)
Determine routines for data pre-processing and quality assurance	(Chapter 4)
Extract typical crop signatures throughout vegetation growth cycle for barley, canola, chickpeas, lentils and wheat	(Chapter 5)
Determine accuracies for crop type discrimination through-out the season	(Chapter 5)
Analyse the satellite data in respect to in situ data such as plant height, above ground wet and dry green biomass, plant water,	(Chapter 6)

soil moisture	
Analyse the satellite data in respect to crop yield	(Chapter 7)
Developing an early phase prototype crop monitoring system	(Chapter 8)
Test which anomalies the farmers can identify in the field based on information gained with the early phase prototype system	(Chapter 8)
Evaluate farmers feedback on early phase prototype testing	(Chapter 9)
Develop a concept for an improved crop monitoring system	(Chapter 9)

4.3 Data sources and data acquisition

This section describes the data collected for the experiment. In situ data were acquired by compiling information from the participating farmers and from extensive field observations conducted by the ALMIS team (author and NRS work colleagues listed in acknowledgement section) in about 40 fields on two farms during satellite data acquisition. Yield data were collected from one participating farmer. Furthermore remote sensing data, such as airborne video, ERS Radar and SPOT satellite data were collected. The preprocessing routines applied to the data were described.

4.3.1 Information from participating paddocks

In 1997 preliminary studies were undertaken with 2 farmers in the Gooroc area; in 1998 the early phase prototype ALMIS trial study was conducted and farmers were invited to participate in the research by contributing ground observations from their fields and giving feedback on the ALMIS monitoring service. Furthermore the farmers demonstrated their interest in the project by paying AUD$200.00 towards the expenses of image hardcopy production and delivery as well as training workshops. Twenty-five farmers responded and signed up for the study. In total, the 1998 ALMIS project provided image data for 598 fields (spread out over approx. 250 km^2) (Figure 4.1).

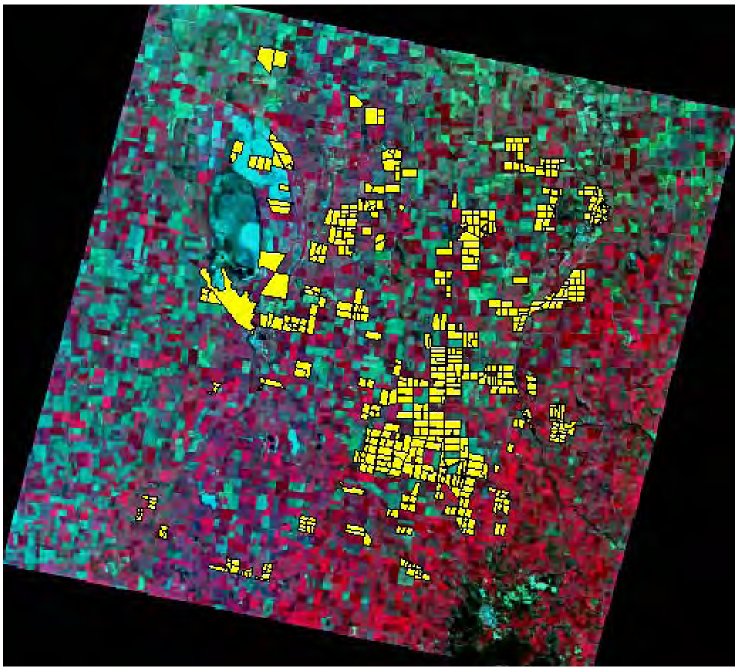
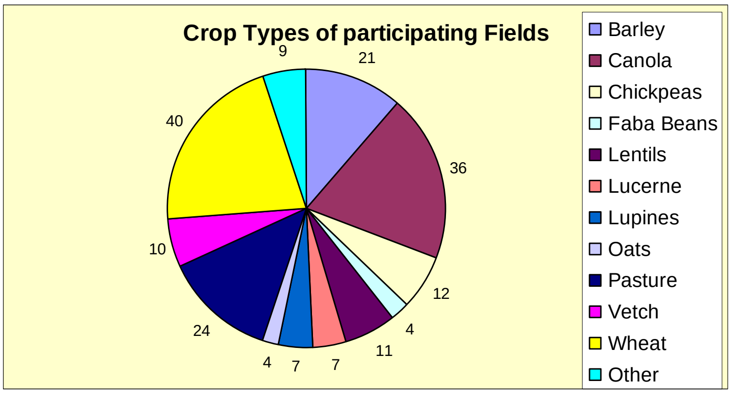


Figure 4.1 Fields participating in the ALMIS prototype trial

All farmers participating in the ALMIS study were supplied with a hardcopy print of the area and asked to mark their fields. The paddock boundaries were then digitized and incorporated in a GIS. Furthermore farmers were asked to provide information on the crop history for each paddock (defined by farm ID, Paddock number, Paddock name); the information required included crop type, crop variety, sowing date, seeder rate, harvest date, yield (tones per hectare) and remarks on the crop (all information was required for the years 1995, 1996, 1997, and 1998). Information on 185 fields was returned by the farmers. The information was entered in the attribute tables of the paddock GIS data layer. Figure 4.2 shows the number of fields for which crop type information was available. In this thesis only fields of the five main grain crops, namely barley, canola, chickpeas, lentils and wheat were investigated.



The category "Other" included: beans, fallow, field peas, linseed, medic clover and sorghum.

Figure 4.2: Number of participating fields for each crop type

During the crop season the farmers were supplied with geo-referenced and colour coded vegetation index images. The farmers field-checked in-homogeneities within the paddock as seen on the images and noted their observations.

At the end of the 1998 crop season a full-day workshop was conducted in February 1999 to compile the farmer's experiences and discuss the field notes. The farmers also summarized value and concerns of the early-phase prototype ALMIS in a questionnaire (see Appendix A) and suggested future developments they would like to see in a crop monitoring system.

4.3.2 Field work in "Super Test Sites"

Extensive field observations in the Gooroc area were conducted during the 1998 crop cycle by the author and colleagues from the ALMIS team. Most components of the field work were conducted as recommended by Cihlar et al. (1987). Field work took place on two and one half days centred around each ERS-2 overpass date.

1998 Field work data collection dates:

DOY	**Date**
168	17/06/1998
203	22/07/1998
238	26/08/1998
273	30/09/1998
308	04/11/1998
343	09/12/1998

In 1998, a total of 234 Fields were sampled during 6 field trips. The location of each sample location was clearly marked on the fence line for subsequent field visits and the distance into the field perpendicular from the fence line was measured. The sampling area in each paddock was homogeneous over a minimum of 60x 60 metres and samples were taken from within that 60x60 metre area. This method was applied to minimize the impact of destructive sampling for 1 m^2 biomass on the remote sensing signal.

A worksheet was used to compile field work information on each paddock. The parameters recorded for each field were as follows:

- Name of observer
- Weather
- Date
- Time
- Paddock name
- Farm ID
- Paddock number
- Coordinates AMG Northing
- Coordinates AMG Easing
- GPS Projection Information
- Crop Type
- Remarks about Phenology
- Crop height
- Stubble height
- Weight 1m^2 biomass (wet)
- Weight 1m^2 stubble (wet)
- Remarks about crop

- Row direction
- Row depth
- Row width
- Weight of 3 soil cylinder samples to determine soil moisture
- Remarks about soil
- Photographs

GPS coordinate

GPS coordinates were collected with a handheld Garmin GPS unit. The unit was left for a minimum of 10 minutes to allow better triangulation.

Crop height

Crop and stubble height were measured with a measure tape on three representative spots.

Biomass

To determine above-ground biomass, a wooden square of 1 m^2 was put on the paddock floor. All biomass within the wooden square was cut and green biomass and dry stubbles were filled in labelled separate paper bags. The bags and biomass were weighed and recorded immediately in the field (to avoid evaporation of water over time). After the field trip the biomass samples were dried for approximately 3-4 days at 70ºC in the drying ovens of the Department of Land and Food Resources at the University of Melbourne. The samples were checked several times until the dry weight had stabilized. Then the biomass samples were weighed immediately to avoid re-hydration from the atmosphere and the dry weight was determined. The weight of the paper bags was subtracted from all measurements.

Soil moisture

Three representative soil samples were taken from each field with a standard soil cylinder and stored in labelled self sealing snap-lock plastic bags. Since the soils were very dry and friable, there were no issues of reduced sample sizes due to soil sticking to the cylinders. Soils were weighed, and dried at 105ºC for 24 hours at the Soil laboratory at RMIT University, and volumetric soil moisture content was calculated (Chilar 1987; Foody, 1991; Hillel, 1998).

Figure 4.3: Farmer 14 conducting soil neutron probe measurements

Furthermore, during each field trip soil moisture was measured with a neutron probe (by farmer 14, on 21 of his paddocks). Details on the paddock specific soil types and conservation farming practices on farm 14 can be found in Imhoff (1996) and Postlethwaite (1998). The measurements were conducted at the following depth below surface: 0-25 cm, 25- 50 cm, 50- 75 cm, 75 -100cm. Profiles for Total Soil Water [mm] were produced, and soil type specific values of the Available Soil Water (ASW) [mm] were calculated. The following extractable lower limits were set for local red and grey soils:

Table 4.2: Extractable water limits for Gooroc red and grey soils

Depth [cm]	**0-25**	**25-50**	**50-75**	**75-100**	**100-125**
Grey soil	35	65	70	80	80
Red soil	20	50	70	80	80

The ASW [mm] for 0- 100 cm was then calculated. Table 4.3 shows an example of the measurement derived values for the "North" paddock on the 22/07/1998.

Table 4.3: Total and available soil water in the North paddock on 22/07/1998

PADDOCK NAME	**NORTH**	
TUBE No.	16	
CROP '98	Wheat	
DEPTH (cm)	**Total Soil Water TSW [mm]**	**Available Soil Water ASW [mm]**
0-25	65	30
25-50	92	27
50-75	84	14
75-100	86	6
ASW (0-100cm)		**77**

4.3.3 Yield maps

Precision farming equipment on combine harvesters (Figure 4.4) allow to record yields of the paddocks that are geo-referenced with a differential GPS unit. Hence digital maps of yield results can be produced. Farmer 14 obtained yield data, using a Micro-Track yield monitor and data logger on a Case International 1680 axial flow harvester. To record the location a Fugro Omnistar DGPS was used and corrected with the Optus satellite and available base stations in Australia. The accuracy was claimed to be sub metre. Yield maps were acquired of seventeen paddocks for the Super Test sites (see Table 4.4; note date reads YYYYMMDD): four maps for canola, four for chickpeas, two for lentil, and seven for wheat fields.

Figure 4.4: Combine harvester in wheat field on farm 14 in 1998

Table 4.4: Details of 1998 yield maps (farm 14)

ID	FIELD NAME	CROP	HARVEST DATE	REMARKS
14-6	Hoyes North	Canola	19981202	complete area
14-11	Wier	Canola	19981204	partial area
14-21	Adelines South	Canola	19981123	partial area
14-23	Adelines	Canola	19981129	partial area
14-10	Gilmour	Chickpeas	19980104	complete area
14-12	Hills	Chickpeas	19981207	complete area
14-13	McKew	Chickpeas	19981228	complete area
14-16	Woolshed	Chickpeas	19990107	complete area
14-3	Shed	Lentils	19981223	partial area
14-4	Fingerboard	Lentils	19981224	partial area
14-2	O'Donnells Nth	Wheat	19981217	complete area
14-5	Hoyes House	Wheat	19981215	complete area
14-14	Jewes	Wheat	19981211	complete area
14-17	Alphalane	Wheat	19981204	partial area
14-18	North	Wheat	19981209	complete area
14-19	Lunar	Wheat	19981209	complete area
14-20	Timber West	Wheat	19981210	complete area

The raw yield data were exported from binary data to ASCII, using the Micro Track card utilities data transfer program. With the Micro-Track grain track utility program yield sensor delays and antenna displacement corrections were performed (a fourteen second delay occurs between the instant of harvesting at the front of the header to the instant of yield measurement by the sensor. Furthermore, the GPS antenna is located 2 metres behind the point where the grain enters the harvester). The corrected data were exported to .dbf file format.

About 15,000 data points were recorded on a typical-sized field. All zeros (typically <350) and extreme high values (typically <10) were removed. These artefacts are caused due to the combine harvester driving over already harvested areas and measuring errors due to stop-start of the harvester. The yield point data were then imported into ARCGIS software (ESRI, 2005) and converted to a raster dataset with the cell size of 10 metres. The mean value of the underlying data points was calculated to derive the value of the pixel.

4.3.4 Airborne video imagery

Figure 4.5: Sample of airborne video image

Before the farmers of the St Arnaud farming community got involved in the ALMIS project, they were conducting their own remote sensing studies of crops. The community collectively acquired a digital (off the shelf) video camera, and farmer 16 (pilot) and farmer 14 (camera operator) recorded images of the paddocks for themselves and their neighbours. To trial how their usual remote sensing method compared to the SPOT vegetation indices supplied by the pilot study to the farmers, video images were acquired from the Super Test Sites on the following dates: 18/06/98, 22/07/98, 30/09/98, 04/11/98, 09/12/98. The author used the data as a visual high resolution reference and additional information to the field work notes. Figure 4.5 shows an example of the airborne video data acquired on 04/11/1998 from farm 3, showing a chickpea paddock with *Ascochyta* blight.

4.3.5 ERS data

ERS Radar data were collected every 35 days throughout the 1998 crop season. However due to header errors in the datasets the images could not be analysed and included in the thesis. For details refer to Appendix B.

4.3.6 SPOT data

SPOT data are the core remote sensing data used and analysed in this thesis. The technical details of the satellites have been described in the Chapter 2, Table 2.2. SPOT Image (FRANCE) and CNES (French Space Agency) awarded the author an ADEMA grant and provided the images for 1998 (Coppa, 1998). The images for 2001 were acquired by the RMIT "CropView" project (Sobels, 2002; RMIT 2002).

	DOY	**Date**	**Sensor**
1998 Data	181	30/06/1998	SPOT 4
	205	24/07/1998	SPOT 1
	221	09/08/1998	SPOT 1
	240	28/08/1998	SPOT 2
	251	08/09/1998	SPOT 2
	287	14/10/1998	SPOT 2
	313	09/11/1998	SPOT PAN
	320	16/11/1998	SPOT 1

2001 Data	210	29/07/2001	SPOT 2
	225	13/08/2001	SPOT 4
	242	30/08/2001	SPOT 2
	255	12/09/2001	SPOT 4
	282	09/10/2001	SPOT 4
	319	15/11/2001	SPOT 4

4.4 Data calibration and processing of the SPOT satellite data

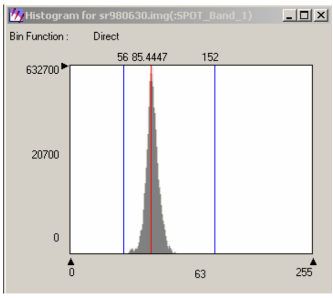
The optical satellite data ordered for the study were SPOT satellite data; they were from path/row location 374-423, processed to level 1A (SPOT, 1998), and were delivered in SPIM format (ACRES, 1998). Before the SPOT data could be used for the early phase prototype crop monitoring system, several preprocessing steps needed to be applied; furthermore quality assurance measures were put in place to ensure that each preprocessing step produced satisfactory accuracy levels. Preprocessed data of equally high levels were essential for model development and model application.

4.4.1 Image data quality

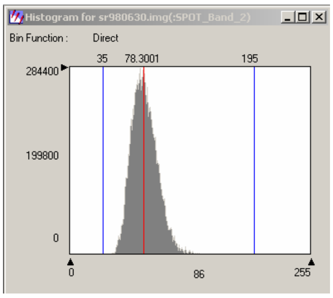
The first step taken in the image preprocessing routines was to evaluate the quality of the data. Images were checked visually for clouds and sensor or processing faults such as image striping. A few small popcorn clouds (*cumulus humilis*) were detected on 8th September 1998; however most of the fields under investigation were unaffected. Fields affected by the clouds were removed. Clouds are often a problem in south east Australian winter while crops are growing. It is essential to have image acquisition programmed as often as possible. In 1998 every SPOT overpass was priority programmed; ideally, nadir images are preferred in data selection. Another quality issue encountered was image striping due to sensor fault; it was detected on the 24th July 1998 image. Hence, the data were excluded from most of the analysis.

After the visual image check, the histograms of the “raw” imagery were obtained. As can be seen in Figure 4.6 the width of the histograms in similar wavelengths is mainly dependant on which SPOT satellite was used. SPOT 4, being a newer satellite in 1998 had a much greater data range in all bands. SPOT 1 and 2 showed their age in diminished width of the histograms, with SPOT 2 still performing better (particular in the NIR, band 3) than SPOT 1. Obviously, the date the image was taken and therefore the amount of biomass present on the ground contribute to some degree to the greater histogram width of SPOT 2 data as well.

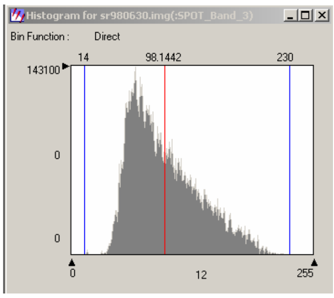
Band 1 Band 2 Band 3



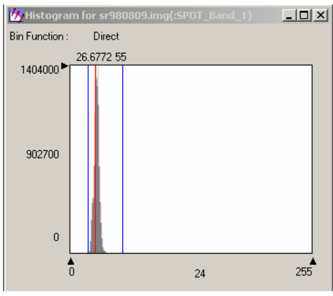
30/06/98 SPOT4, Band 1



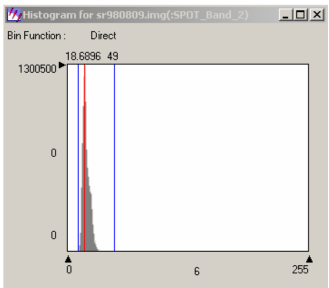
30/06/98 SPOT4, Band 2



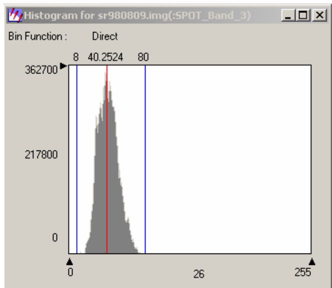
30/06/98 SPOT4, Band 3



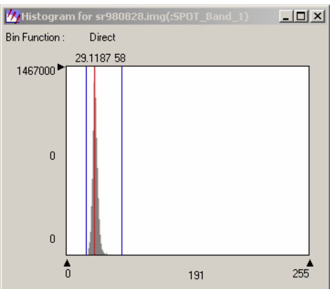
09/08/98 SPOT1, Band 1



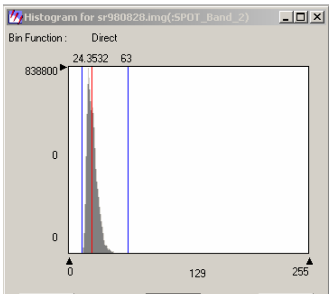
09/08/98 SPOT1, Band 2



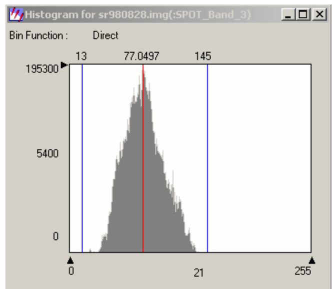
09/08/98 SPOT1, Band 3



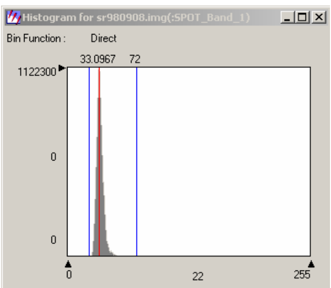
28/08/98 SPOT2, Band 1



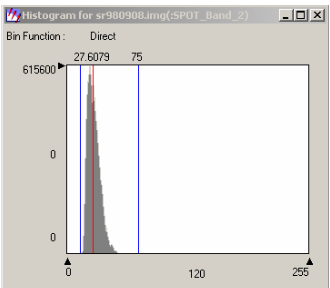
28/08/98 SPOT2, Band 2



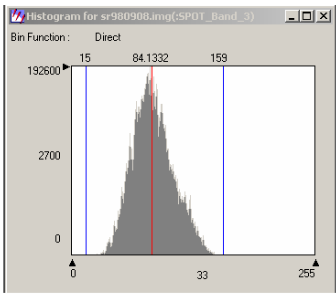
28/08/98 SPOT2, Band 3



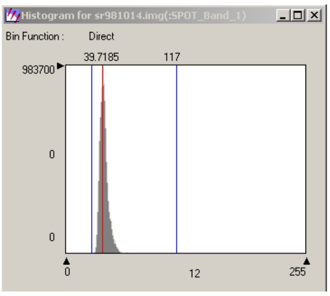
08/09/98 SPOT2, Band 1



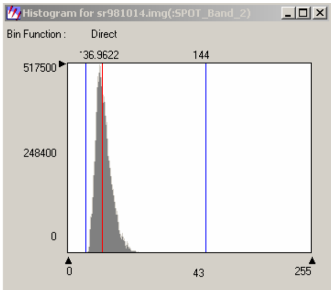
08/09/98 SPOT2, Band 2



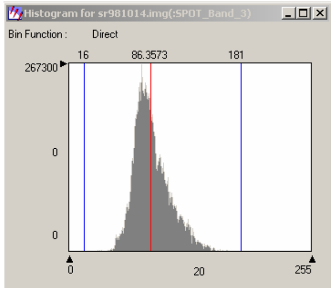
08/09/98 SPOT2, Band 3



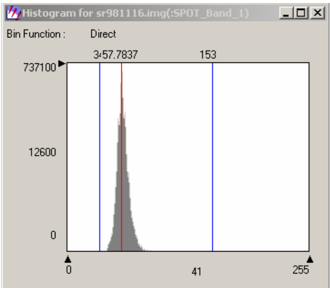
14/10/98 SPOT2, Band 1



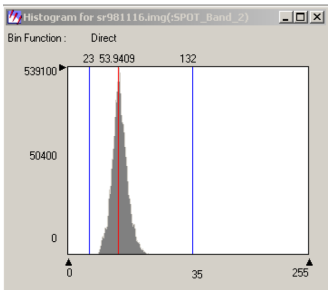
14/10/98 SPOT2, Band 2



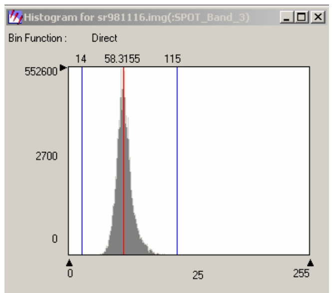
14/10/98 SPOT2, Band 3



16/11/98 SPOT1, Band 1



16/11/98 SPOT1, Band 2



16/11/98 SPOT1, Band 3

Figure 4.6: Histograms of SPOT Band 1-3 in 1998 (see text for full discussion)

4.4.2 Geometric corrections

The SPOT data were geo-referenced to the Department of Natural Resources and Environments 1:25,000 digital road dataset (NRE, 1998). Evenly distributed Ground Control Points (GCP) were selected per scene and the ERDAS-SPOT model (Pouncey et al. 1999) was applied to rectify the images, taking into account the satellite incidence angle and a constant elevation parameter (140 metres above sea level; the area of interest was very homogeneous). A nearest neighbour algorithm (Pouncey et al. 1999) was used to warp 20 metres pixels to map projection UTM, Zone 54, with Datum WGS 84.

After warping the imagery was taken though a two-fold quality assurance (QA) procedure to ensure satisfactory geometric accuracy levels. Firstly, a threshold was set at an over-all RMS error levels in the sub-pixel range (<1 equivalent to <20 metres). Table 4.5 shows that all images pass the criterion set by the QA.

Table 4.5: Summary of RMS errors in 1998 SPOT satellite geometric corrections

SENSOR	IMAGE	RMS X	RMS Y	TOTAL RMS
SPOT	30/06/98	0.5907	0.6687	0.8922
SPOT	09/08/98	0.5787	0.8111	0.9964
SPOT	28/08/98	0.5555	0.7945	0.9694
SPOT	08/09/98	0.4405	0.7217	0.8455
SPOT	14/10/98	0.7417	0.5875	0.9462
SPOT	16/11/98	0.6355	0.6910	0.9388

The second quality assurance check was a displacement measure on six selected road crossings; it was obtained between the image and the 1:25,000 road vector cover. The distance and angle of displacement was determined. A threshold of a maximum of 1.5 pixels (equivalent to 30 metres) was set. This criterion was determined by a sub-pixel image-to-image fit, and a possible 12 metres error in the vector dataset. Figure 4.7 shows the technique applied to obtain the displacement measure.

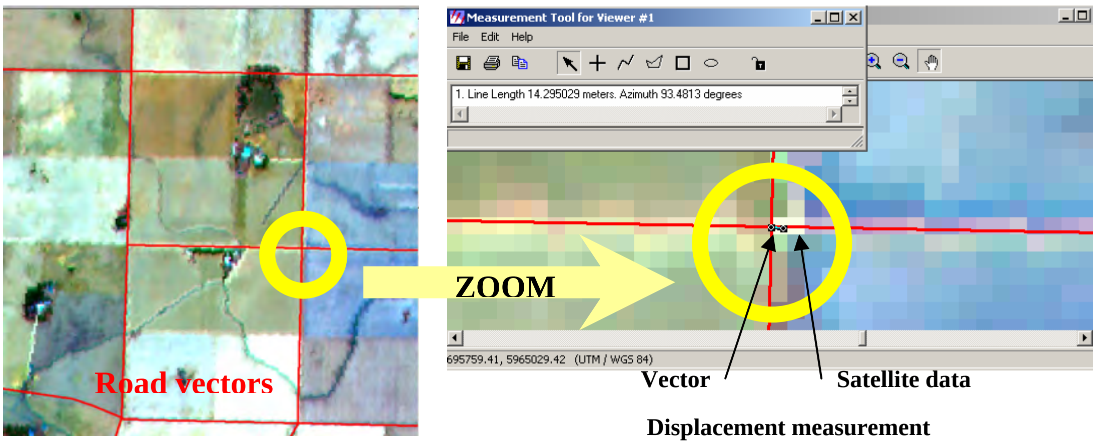
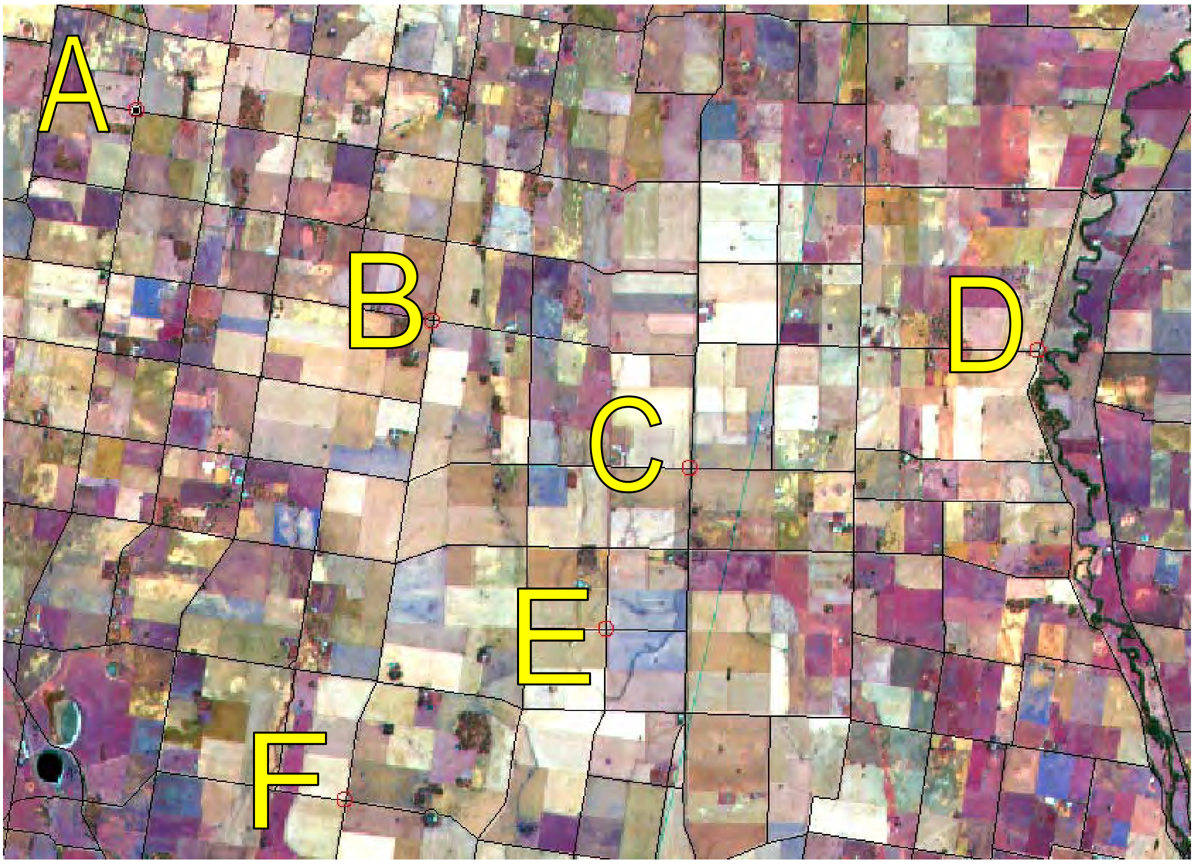


Figure 4.7: Displacement measurement between road vector and road on satellite image (see text for full explanation)

Road vectors are marked in red; the right image is a zoomed-in version of the left image. Note the two arrows pointing at two black points on the road vector indicating the vector and satellite image location of the specified road intersection. To determine the displacement, the distance and angle between the road vector and the satellite image were measured.

In the example in Figure 4.7 a displacement of 14.3 metres, azimuth 93.5 degrees was observed. The displacement was measured on six checkpoints in the satellite image. The same checkpoints were used for the other SPOT satellite images acquired in the 1998 season. Figure 4.8 shows the location of the six checkpoints A to F in the image and gives the displacement measurement results in 1998. All checkpoints passed the quality assurance requirements and were better than the 30 metres threshold limit.



Point	X	Y	Point	X	Y	Point	X	Y
A	686252	5975369	B	692188	5971158	C	704283	5970551
Image	Distance	Angle	Image	Distance	Angle	Image	Distance	Angle
19980630	12.41	268	19980630	6.1	242	19980630	19.05	21
19980809	20.73	277	19980809	14.85	287	19980809	16	313
19980828	20.68	272	19980828	9.73	257	19980828	18.66	352
19980908	9.98	223	19980908	13.83	158	19980908	9.41	289
19981014	17.21	228	19981014	20.71	184	19981014	20.61	358
19981116	20.33	279	19981116	5.46	192	19981116	12.09	297

Point	X	Y	Point	X	Y	Point	X	Y
D	697313	5968193	E	695642	5964974	F	690423	5961518
Image	Distance	Angle	Image	Distance	Angle	Image	Distance	Angle
19980630	4.69	268	19980630	4.69	88	19980630	8.31	43
19980809	14.5	14	19980809	5.91	62	19980809	12.1	340
19980828	8.05	17.09	19980828	2.06	358	19980828	6.51	17
19980908	10.56	88	19980908	14.38	88	19980908	14.34	54
19981014	10.5	189	19981014	9.75	167	19981014	1.76	178
19981116	2.05	88	19981116	1.61	88	19981116	4.12	358

The coordinates are given in AMG, UTM 54S. The date reads YYYYMMDD. The distance is measured in metres. The angle is measured in degrees of North.

Figure 4.8: Quality Assurance displacement measure of six checkpoints in SPOT satellite images (see text for full explanation)

4.4.3 Atmospheric corrections

Satellite data for precision farming in south east Australia were acquired between June and December. This resulted in different illumination conditions, which alone could cause significant variations in the pixel values, even from invariant targets. Furthermore, different atmospheric conditions caused even greater variations of the spectral response of the imagery (Schowengerdt, 1997; Asrar, 1989; Richter, 1996). To compare multi-temporal images in absolute terms, radiometric and atmospheric corrections were necessary. It was also essential to compensate for gain and offset parameters of the different SPOT sensors.

ATCOR (Geosystems, 1998) is a module of ERDAS IMAGINE, in which both radiometric and atmospheric corrections can be modelled. In addition the program is able to mask clouds and haze. The hazy areas can be treated and visual image quality improved significantly while the cloud mask allows exclusion of cloudy areas from further processing. The algorithm is based on “A spatially adaptive fast atmospheric correction algorithm” by Richter (1996) and corrects for atmospheric conditions (air pressure, temperature, humidity, aerosol type), ground elevation, solar zenith angle and visibility. The SPOT DN values were converted to reflectance values (a factor four was applied to maximize the use of the data range for 8 bit unsigned data). Table 4.6 shows the relevant variables applied to the atmospheric correction.

Table 4.6: Atmospheric correction parameters

Date	30/6/98	9/8/98	28/8/98	8/9/98	14/10/98	16/11/98
Sensor	SP4-2	SP1-1	Sp2-1	Sp2-1	Sp2-1	Sp1-1
Incidence angle	16.1	3.20	9.99	-9.68	3.88	-3.57
Solar zenith	63	59	53	50	36	28
Gain B1	4.34128	0.83687	0.861	0.837	0.837	0.811
Gain B2	5.14692	0.99332	1.008	0.993	0.993	0.802
Gain B3	3.62988	0.17497	1.178	1.175	1.175	0.812
Gain B4	13.31878	N/A	N/A	N/A	N/A	N/A
Profile*	Midlat summer	Midlat summer	Midlat summer	Midlat summer	Midlat summer	Fall
Aerosol type	Rural	Rural	Rural	Rural	Rural	Rural
Visibility	80	60	60	60	60	40

*The atmospheric profiles are described by Geosystems, 1999.

The spectral responses of several targets were tested, some of which were considered to having minimum change throughout the season ("invariant targets") to ensure the quality of the radiometric and atmospheric corrections. The accuracy of the calibration was mostly within 5% [reflectance]. Following is a table containing the targets used for the atmospheric correction quality assurance (QA) procedure, their centre position in UTM WGS84 coordinates, and the number of pixels used to obtain a mean value.

Table 4.7: Details of invariant calibration targets

Name of Target	X Position	Y Position	Number of Pixels
Water	684672	5962380	110
Forest	699651	5945034	137
Clay Pit	707250	5948532	29

Figures 4.9, 4.14 and 4.19 show the areas in the image from which the invariant targets were selected. A visualization of the respective spectral behaviour for the three SPOT bands follows. For comparison the graphs for the 2001 SPOT data of the same

invariant targets were included. The graphs on the left show the values for the target "water" (Figure 4.10, 4.12), "forest" (Figure 4.15, 4.17) and bare clay soil in an "open pit" (Figure 4.20, 4.22) before calibration, the graphs on the right after calibration ("water" Figure 4.11, 4.13, "forest": Figure 4.16, 4.18 and "open pit": Figure 4.21, 4.23). The values after calibration were in % reflectance, while the values before calibration were expressed as DN values. A clear seasonal trend could be observed in the pre-calibration data. The values from 30 June 1998 (DOY 181) were furthermore atypical due to the use of Spot 4 data; the calibration of the dark invariant target "water" in the June image posed as difficult- the values were between zero and one per cent and did therefore not show on the graph. However since the brighter targets "forest" and "open pit" could be calibrated, it was decided not to exclude the June 1998 data. As can be observed the calibrated data were comparable between the two years.

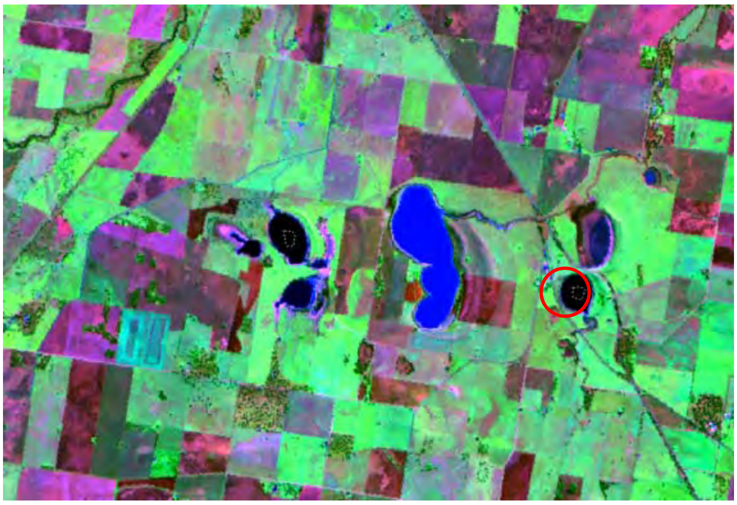


Figure 4.9: Atmospheric correction invariant reference target "Water" in SPOT satellite image

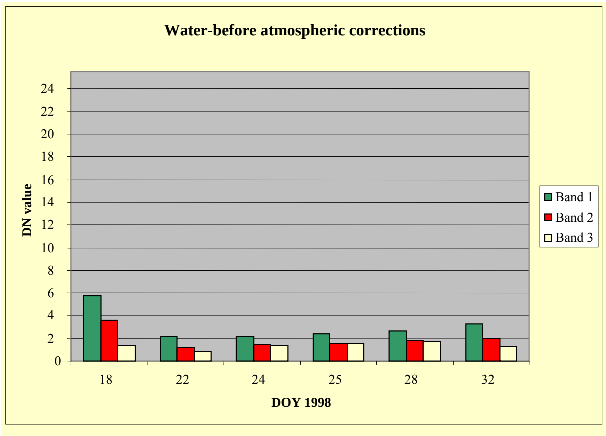


Figure 4.10: Invariant reference target "Water" in 1998 before atmospheric correction

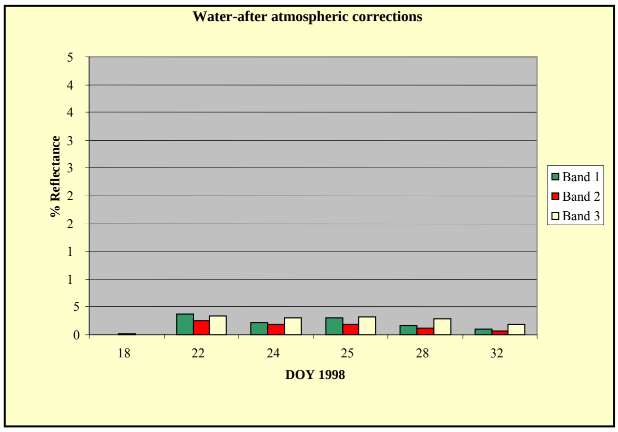


Figure 4.11: Invariant reference target "Water" in 1998 after atmospheric correction

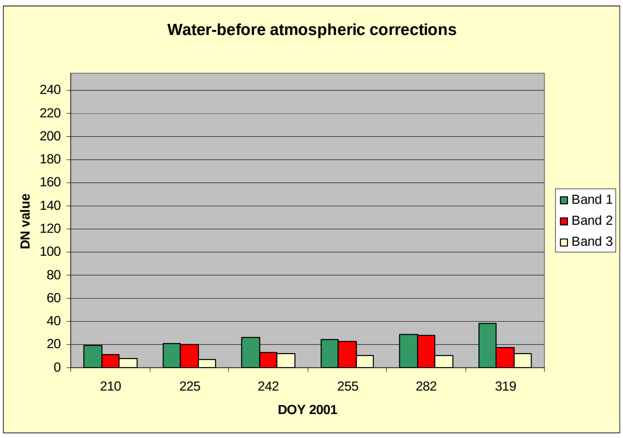


Figure 4.12: Invariant reference target "Water" in 2001 before atmospheric correction

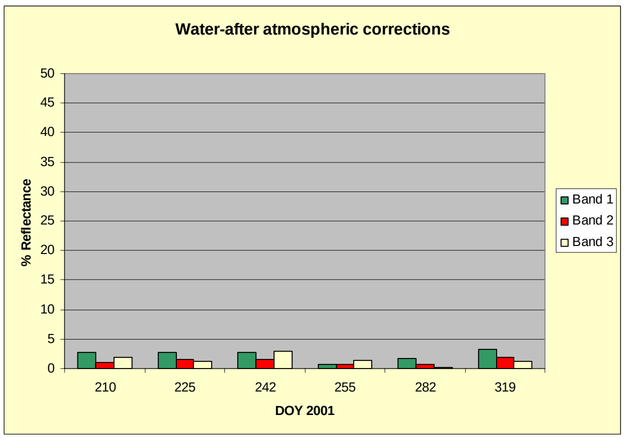


Figure 4.13: Invariant reference target "Water" in 2001 after atmospheric correction

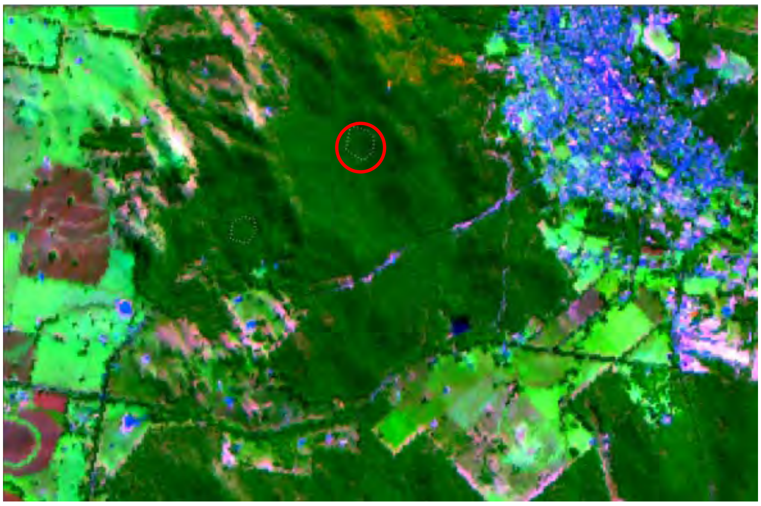


Figure 4.14: Atmospheric correction invariant reference target “Forest” in SPOT satellite image

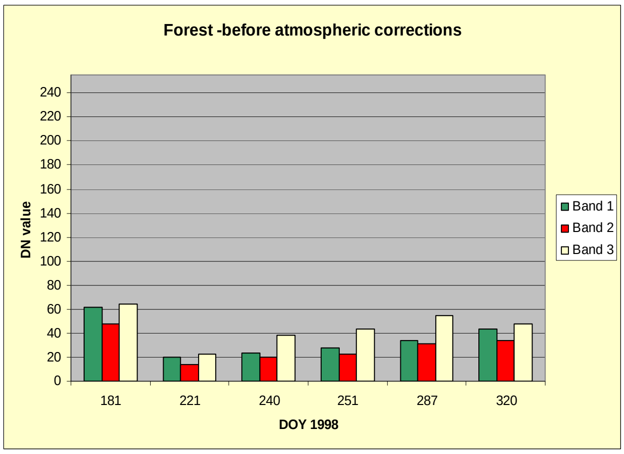


Figure 4.15: Invariant reference target “Forest” in 1998 before atmospheric correction

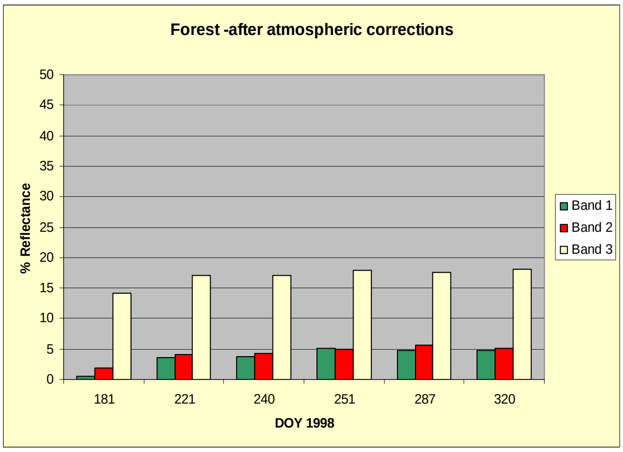


Figure 4.16: Invariant reference target “Forest” in 1998 after atmospheric correction

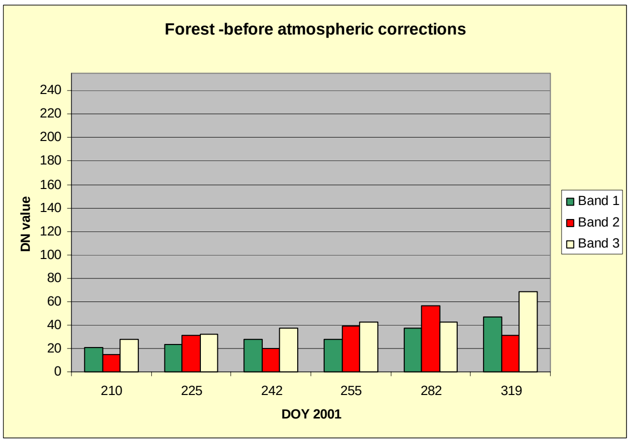


Figure 4.17: Invariant reference target “Forest” in 2001 before atmospheric correction

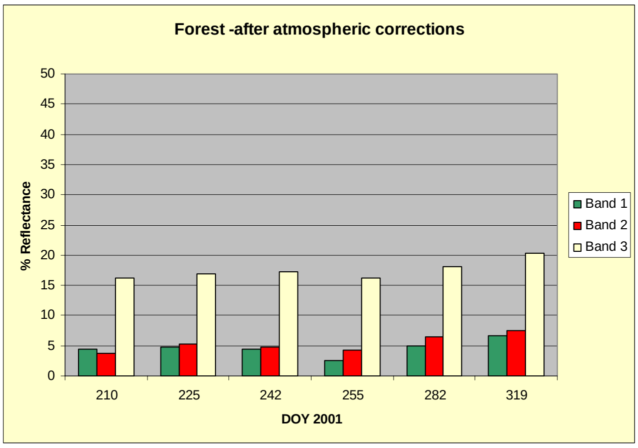


Figure 4.18: Invariant reference target “Forest” in 2001 after atmospheric correction

Figure 4.19: Atmospheric correction invariant reference target "Open Pit" in SPOT satellite image

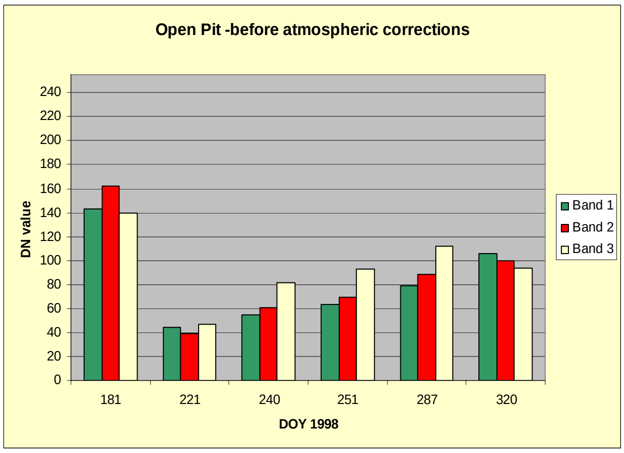


Figure 4.20: Invariant reference target "Open Pit" in 1998 before atmospheric correction

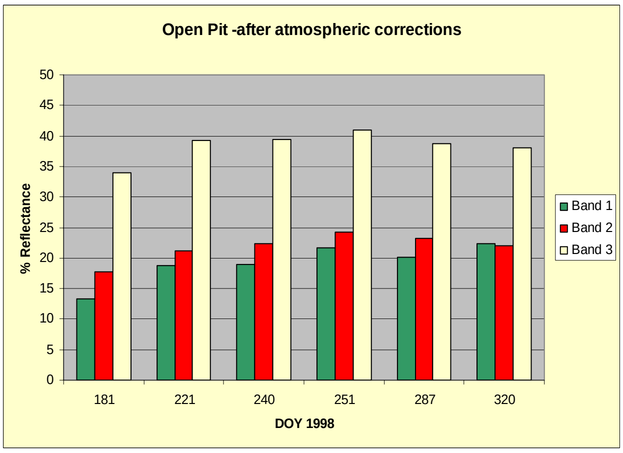


Figure 4.21: Invariant reference target "Open Pit" in 1998 after atmospheric correction

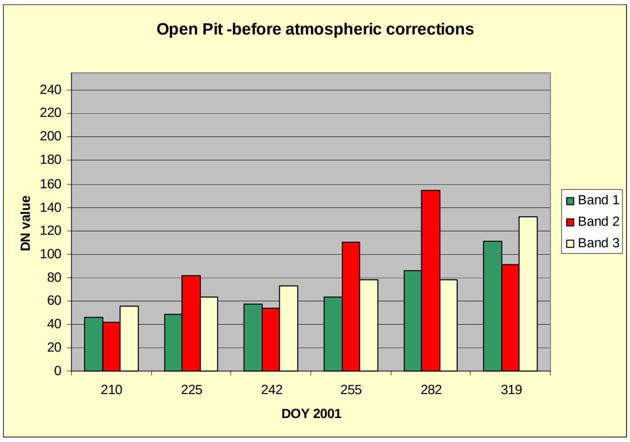


Figure 4.22: Invariant reference target "Open Pit" in 2001 before atmospheric correction

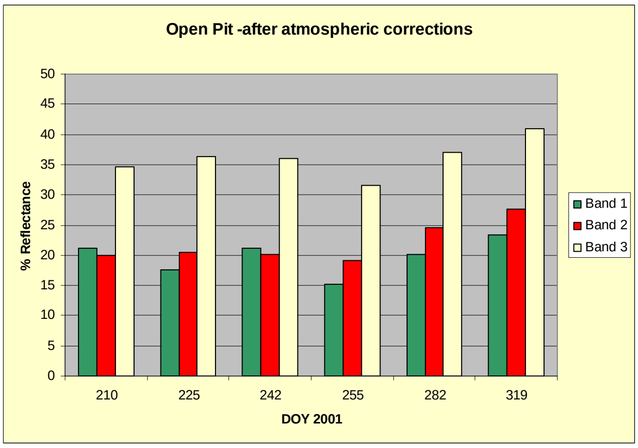


Figure 4.23: Invariant reference target "Open Pit" in 2001 after atmospheric correction

NDVI testing of atmospherically corrected data

A further test was applied to verify the stability of invariant targets. From the SPOT satellite data the Normalized Difference Vegetation Index (NDVI) was calculated:

$$NDVI= [R_{NIR}-R_R]/ [R_{NIR}+R_R] \text{ (Rouse, 1979)}$$

It was expected that after appropriate radiometric and atmospheric corrections the NDVI would remain at a consistent level throughout the crop season, and across multiple years. Figure 4.24 and 4.25 show the NDVI of the invariant target "open pit" without and with calibration in 1998. It can be observed that the curvature in the uncorrected data becomes mostly linear in the corrected data. A similar even more pronounced levelling effect can be observed in the 2001 data (Figure 4.26 and 4.27) for the same invariant target.

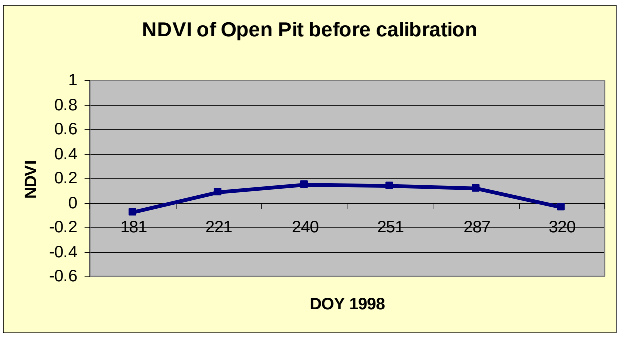


Figure 4.24: NDVI in 1998 of invariant target "Open Pit" before atmospheric corrections

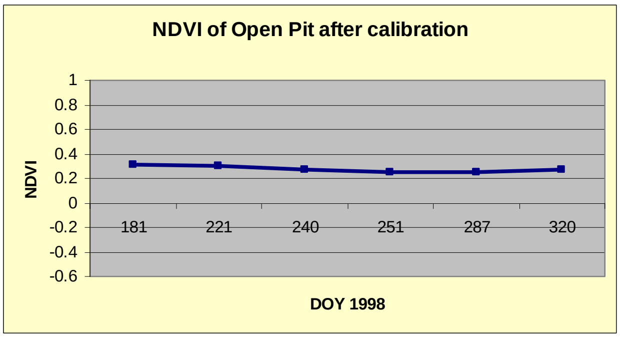


Figure 4.25: NDVI in 1998 of invariant target "Open Pit" after atmospheric corrections

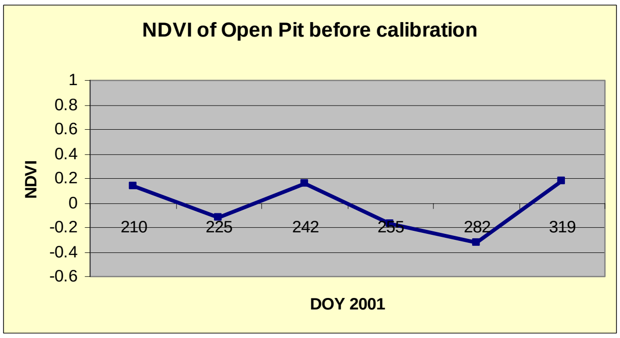


Figure 4.26: NDVI in 2001 of invariant target "Open Pit" before atmospheric corrections

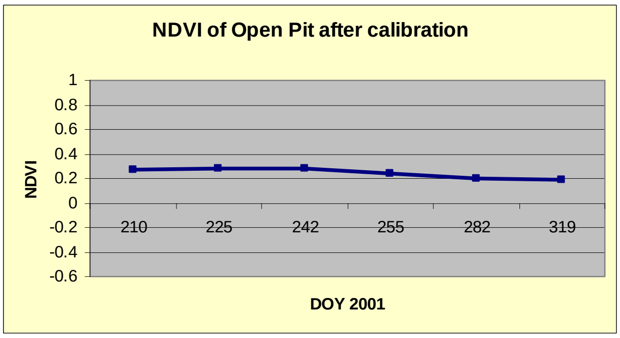
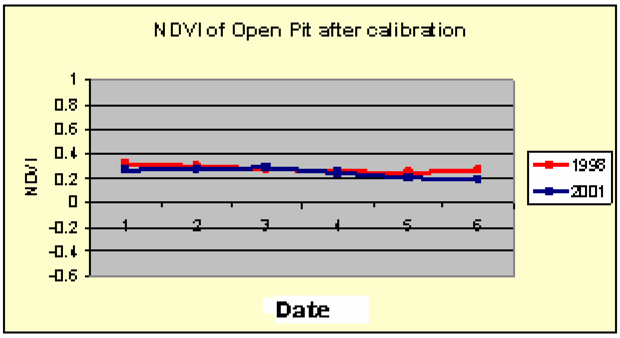


Figure 4.27: NDVI in 2001 of invariant target "Open Pit" after atmospheric corrections

Thus the corrected data of both years (Figure 4.28, projected on top of each other) showed very similar values. The accuracies demonstrated in this chapter were considered adequate and allowed the subsequent research to be undertaken.



DOY	1998	2001
Date 1	181	210
Date 2	221	225
Date 3	240	242
Date 4	251	255
Date 5	287	282
Date 6	320	319

Figure 4.28: Comparison of NDVI in 1998 and 2001 of invariant target "Open Pit" after atmospheric corrections

4.5 Conclusions

In this chapter the conceptual research design that was applied to the experiment was described. Satellite remote sensing data and ground observations of crops were collected in the same spatial extend at multiple acquisition dates in 1998 to study the relationship between the remote sensing and ground data. Collected were information on the paddocks supplied by the farmers, field work (crop height, wet and dry biomass soil moisture measurements, photographs etc.) gathered by the ALMIS team, yield maps at harvest, airborne videos and satellite data. The preprocessing of the data was described. In particular the SPOT satellite data needed to be calibrated before use for the study. The SPOT data were visually checked for clouds and system errors. Furthermore the histogram distribution was assessed. A nearest neighbour SPOT model algorithm was used to warp the imagery to UTM WGS 84 projection, considering the incident angle and a constant elevation factor. Richter's (1996) radiometric and atmospheric correction algorithms were applied. The quality of the preprocessing routines was assessed. For the geometric corrections a RMS error under one pixel and a displacement measure better than 30 metres (between the 1:25,000 road vectors and the satellite image) on six prescribed locations in the image was requested. The radiometric and atmospheric corrections were assessed on three invariant targets with dark, medium and bright reflectance values (water, forest, open pit). The consistencies of the spectral values were under 5% in most cases, with a rare worst case under 10%. An additional testing of the consistency of the NDVI values of an invariant target throughout the season and across multiple years confirmed the adequacy of the corrections for the subsequent research.

5. Use of remote sensing to determine baseline spectral properties and discrimination accuracies of crop types

5.1 Introduction

To discriminate between healthy thriving crops and crops that need attention with prescription farming measures, a database of typical crop spectra is needed. Since crops change substantially throughout the crop season due to factors such as their phenological development, it is necessary have spectral baselines that incorporate the temporal aspect. Multitemporal satellite data can be used for this purpose. Hence in this chapter the use of satellite data to obtain spectral properties of "typical" crop fields such as barley, canola, chickpeas, lentils and wheat is examined. The temporal developments of the crop "signatures" are characterized and discussed. It is important to understand how the spectral properties of typical crop fields appear in remote sensing data in order to delineate crop fields that have atypical behaviour due to very high or low crop performance; this information is most relevant for precision farming applications.

Farmers themselves do not necessarily need to receive information from remote sensing satellites on the crop type planted on their fields; they planted the crop and hence know what they planted. But it is necessary for the crop monitoring system to have accurate information on crop type in the monitored fields as crop parameter and yield estimates are crop type specific. When subscribing the paddock to the satellite monitoring service the farmers declared the crop types of their fields. However, it was found that occasionally an error occurred in the process and the wrong crop type was assigned to a field. Crop type discrimination made verification possible confirming that the fields were the crop type entered by the farmer and any discrepancies in the database were flagged for further investigation. Hence the accuracies for crop type discrimination with satellite imagery at various points of time in the crop season were investigated.

5.2 Methods

The focus of the analyses were the grain crops barley, canola, chickpeas, lentils and wheat. To characterize the spectral properties of these crops in the Gooroc study area in Victoria, SPOT satellite data for 1998 and 2001 were obtained, processed and analysed (Figure 5.1). Satellite data processing involved a number of steps to generate information about the crop type.

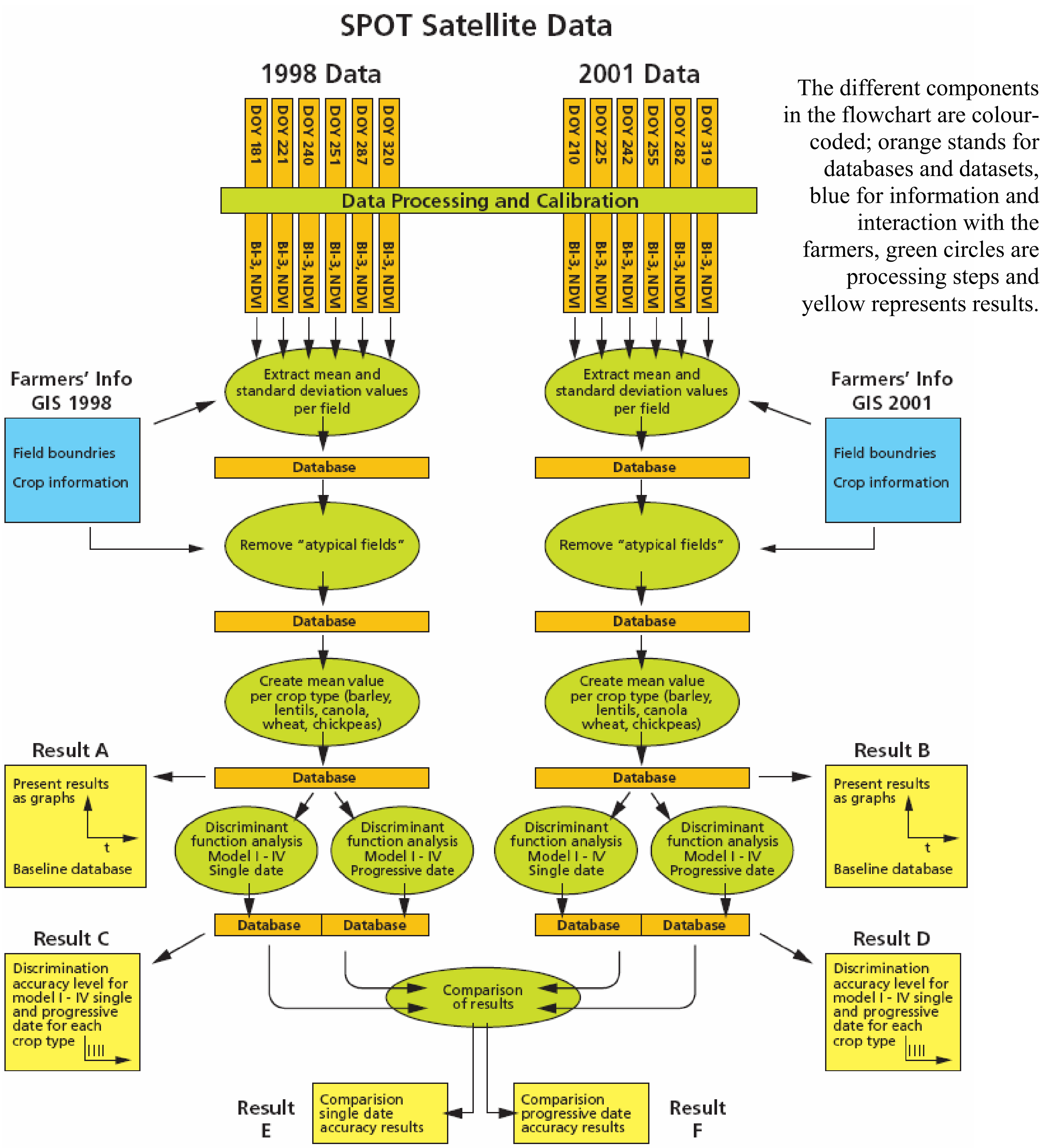


Figure 5.1 Overview of the steps involved in retrieving typical crop signatures and developing crop type discrimination models

5.2.1 Data

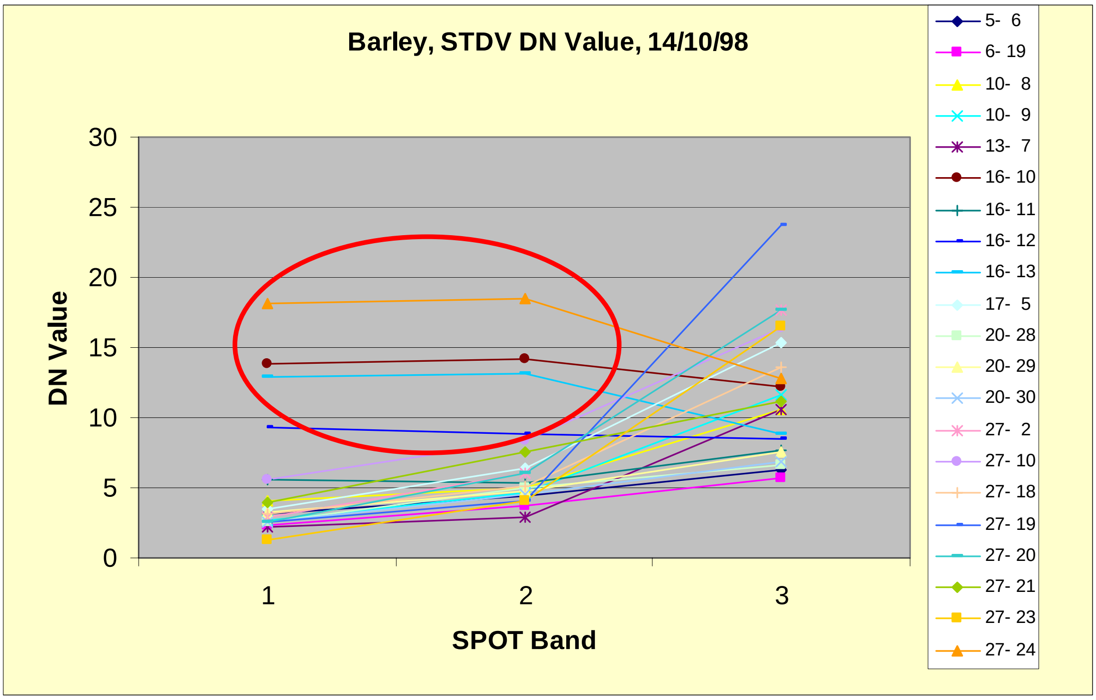
Data used in the analysis presented here were the geo-referenced and atmospherically corrected SPOT data from 1998 and 2001. Furthermore crop type data (barley, canola, chickpeas, lentils and wheat), comments from the 1998 farmer's paddock information and the 2001 CropView project were used. All datasets were described in Chapter 4.

5.2.2 Data extraction

Statistical information of the crop fields was derived from the multitemporal SPOT satellite data. Using the vector cover of the field boundaries, for each field the mean value and standard deviation were calculated with the zonale attribute tool in ERDAS Imagine from the SPOT data on all acquisition dates. The database components of the vector files (dbf format) were used in the software packages Excel and JMP for further investigations.

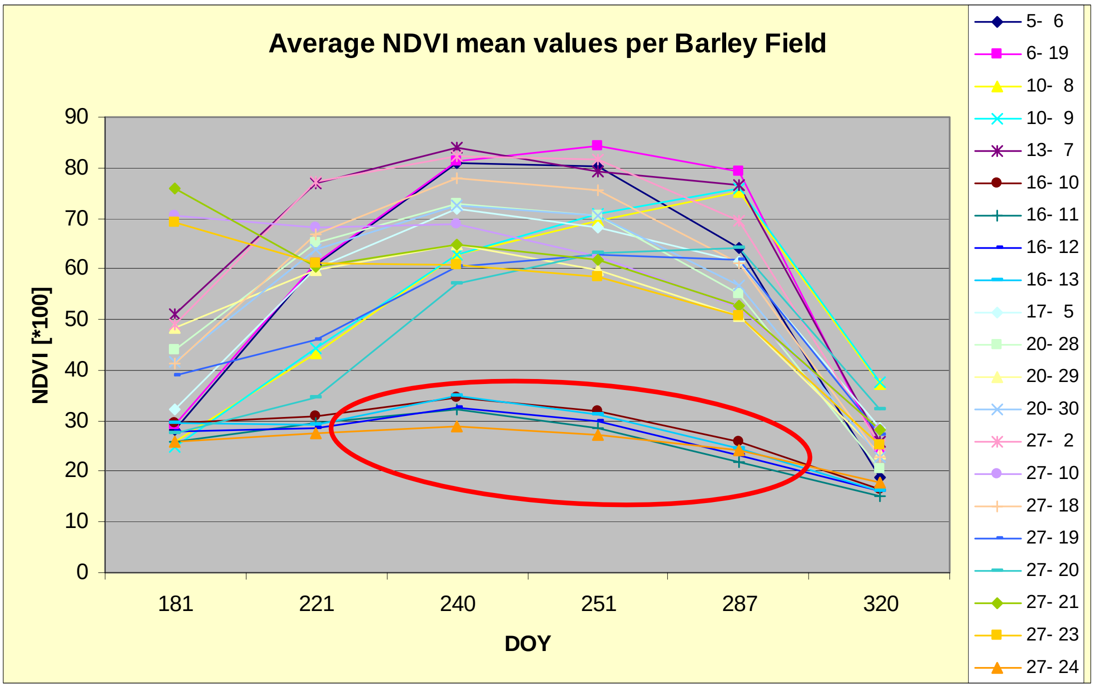
5.2.3 Removal of atypical fields

In order to create a representative baseline dataset of crops in south east Australia, it was necessary to discriminate between "typical" and "atypical" crop fields. In some fields, crop problems and conditions were reflected in the remote sensing data. The causes of these issues were for example crop diseases, pests, or management related; they were known from the comments the farmers had provided. To study the extent of the anomalies in spectral crop properties, data were summarized in graphs. Graphs were created for each mean and standard deviation (n=2), of the 3 SPOT bands and the NDVI data (n=4) on each acquisition date (n=6), for each crop type (n=5). Figure 5.2 demonstrates the methods applied to evaluate atypical fields in the barley baseline dataset. Clearly, fields 16-10, 16-12, 16-13 and 27-24 had much higher standard deviation in SPOT band 1 and 2 than the other barley fields. The atypical behaviour was observed for the same barley fields in the NDVI time series. Figure 5.3 shows the NDVI value for each acquisition date (DOY) of all barley fields in the study.



The standard deviation of the pixels within each barley field for the 3 SPOT bands on the 14th October 1998- DOY 287 is given. The legend reads aa-bb, with aa being the farmer's ID number, and bb being the field number. Note: Y axis DN values include the multiplication factor 4 of the calibrated reflection data to better utilize 8 bit data.

Figure 5.2 Standard deviations for barley field as at 14/10/1998



Atypical spectral behaviour of barley in 1998 is circled in red. The legend reads aa-bb, with aa being the farmer's ID number, and bb being the field number.

Figure 5.3: NDVI mean values of barley field throughout the crop season 1998

The fields circled in red developed differently than all the other barley fields. These fields were located in close vicinity of each other in an area on the edge of Lake Bullock and were waterlogged, thus not producing a comparable biomass to the other barley fields. The circled fields were removed from the dataset that was used to calculate the typical barley baseline SPOT signature.

The crop types canola, chickpeas, lentils and wheat were investigated in a similar manner and atypical fields were removed.

The reasons for atypical crop signatures were: multiple crop types on one field (i.e. 80% barley, 20% lupins), errors farmers had made when supplying crop type information (i.e. a field declared by a farmer to be a lentil field was found to display a typical canola behaviour and was in fact canola) and fields heavily affected by crop pests and diseases, hence having very sparse green vegetation.

5.2.4 Calculation of crop type mean values from all "typical" paddocks

All "typical" fields (data table is attached in Appendix C) were averaged for each acquisition date and for each crop type; the averaged values were determined for each SPOT band (both for mean data and respective standard deviations) as well as the NDVI (and standard deviation). In effect, data from Figure 5.3 were averaged in Figure 5.4.

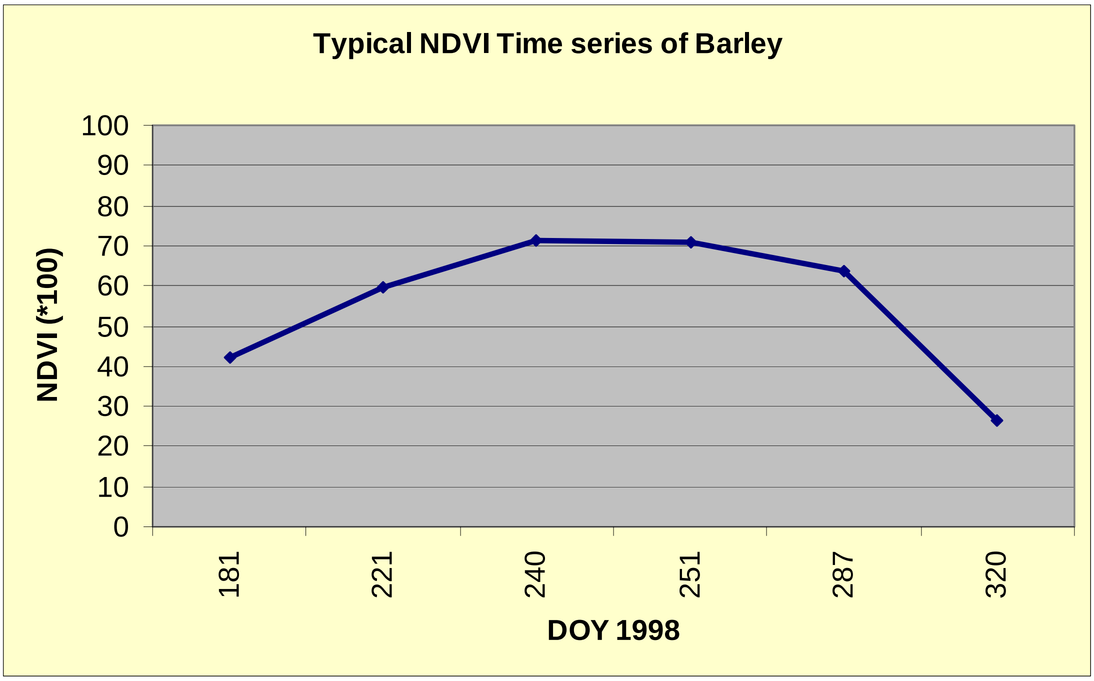


Figure 5.4 Averaged NDVI values of barley fields throughout the crop season 1998

The same method was applied to the SPOT data set from 2001. Typical crop signatures were derived to be able to compare the 2001 data with the 1998 data and to determine if similar patterns could be observed across multiple years.

5.2.5 Single Date Models for crop type identification

Models to discriminate the five crop types from each other were developed. Discriminant Analysis was chosen as the method to conduct the classification in this study. Discriminant analysis is appropriate for situations in which a categorical variable (crop type) is classified based on values of continuous variables (band 1-3 reflectance and NDVI values as well as their standard deviation). The discrimination is most effective when there are large differences among the mean values of the different groups. Larger separation of the mean makes it easier to determine the classifications. The classification of values is completed using a Discriminant function. The function is quite similar to a regression function- it uses linear combinations of the continuous values to assign each observation (paddock) into a categorical group (crop type) (Sall, J. et al, 2005).

Model accuracies were determined for each of the six acquisition dates, based on a single date model. This meant the classification accuracies for barley, canola, chickpeas, lentils and wheat were determined using only the data of the first data acquisition date (DOY 181). Four different models were trialled for DOY 181:

I. The first model using only the mean values from band 1-3 (3 statistical input parameters)

II. The second model tested the mean values from band 1-3 and the NDVI (4 statistical input parameters).

III. In the third model the mean values of band 1-3 as well as their respective standard deviations (6 statistical input parameters) were used.

IV. The mean values from band 1-3, their respective standard deviations, as well as the NDVI and the standard deviation of the NDVI (8 statistical input parameters) were entered into the fourth model.

This procedure (4 different models) was repeated, using only data of the second acquisition date (DOY 221), thereafter using only data from DOY 240 etc. The calculations were done in the statistical software package JMP. For each model the results for each crop type were displayed in a contingency table and a related mosaic plot (Hartigan and Kleiner, 1981; Friendly, 1994).

Furthermore, the overall accuracy of the model was expressed in an Rsquare (U). Rsquare(U) is the proportion to the total uncertainty attributed to the model fit. It is computed as:

U= (-log likelihood for Model)/ (-log likelihood for C.Total)

The negative log likelihood plays the same role as sums of squares in continuous data. Corrected total (C.Total) is measured in degrees of freedom, and computed as N-(r-1), where r is the number of response levels. The degrees of freedom for Model are used to compute the response rate for each factor level and are equal to (s-1)(r-1), where r is again the number of response levels and s is the number of factor levels. An Rsquare of 1 indicates that the factors completely predict the categorical response. An Rsquare of 0 insinuates that there is no gain from using the model instead of fixed background response rates (Sall et al, 2005).

5.2.6 Progressive Date Models for crop type identification

Crops change phenologically and important information can be found on the time scale. Further investigations therefore included the dimension of time in the models. The same discriminant function approach as described in 5.2.6 was taken, but this time not only the information obtained from one selected acquisition date was used, but from multiple dates. The dates were used in a progressive manner to determine the best model results that could be obtained at a certain time in the crop season, with inclusion of information from previous acquisition dates. For example, the DOY 221 information also included the previously obtained DOY 181 information. DOY 240 also included information from DOY 221 and 181.

5.2.7 Comparison of crop type accuracy results from 1998 with 2001 data

To determine if the crop type accuracies obtained from the 1998 data models were compared to other years, models following the same approach were calculated for the 2001 data. The difference between the Rsquare (U) values of models was then calculated between the year 1998 and 2001; the calculations were computed for the single date models and the progressive date models, respectively. The dates were matched to each other as follows:

	1998	**2001**
Date 1	DOY 181	DOY 210
Date 2	DOY 221	DOY 225
Date 3	DOY 240	DOY 242
Date 4	DOY 251	DOY 255
Date 5	DOY 287	DOY 282
Date 6	DOY 320	DOY 319

The difference for date 1 was computed as DOY 181 – DOY 210. A result with minimal difference would confirm consistency of crop type accuracy over multiple years.

5.3 Results

5.3.1 Presentation of time series of typical crop reflectance

It was observed in the typical spectral properties for each crop type that as the amount of green biomass on the ground increased, so did the absorption in band 2 (red wavelength) and the reflectance in band 3 (near infrared wavelength). During senescence the crops had reduced amounts of green biomass and hence the reflectance in band 3 decreased coupled with an increase in band 2. The photographs that were taken of each field during the field work in 1998 also showed these phenological crop specific developments throughout the season. As an example one selected field of each crop type was included.

Barley

The spectral signature of barley as seen by SPOT started with a soil signal at the end of June 1998 (DOY 181) with very little green biomass present in the field. Then the plants developed (until DOY 251), resulting in reduced red reflection (band 2) due to chlorophyll absorption and increased near infrared reflection (band 3) caused by scattering on internal cell structures. Towards the end of the crop season (DOY 320), the barley ripened to senescence and thus the signature showed little photosynthetic activity. The 1998 time series (Figure 5.5) was similar in pattern to the 2001 time series (Figure 5.6), however the 2001 data were temporally shifted when compared to the 1998 data, as the vegetation emerged later in the season. Figure 5.5 and Figure 5.6 show the SPOT spectral properties of 1998 and 2001 while Figure 5.7 show photographs of a selected barley field in the 1998 season.

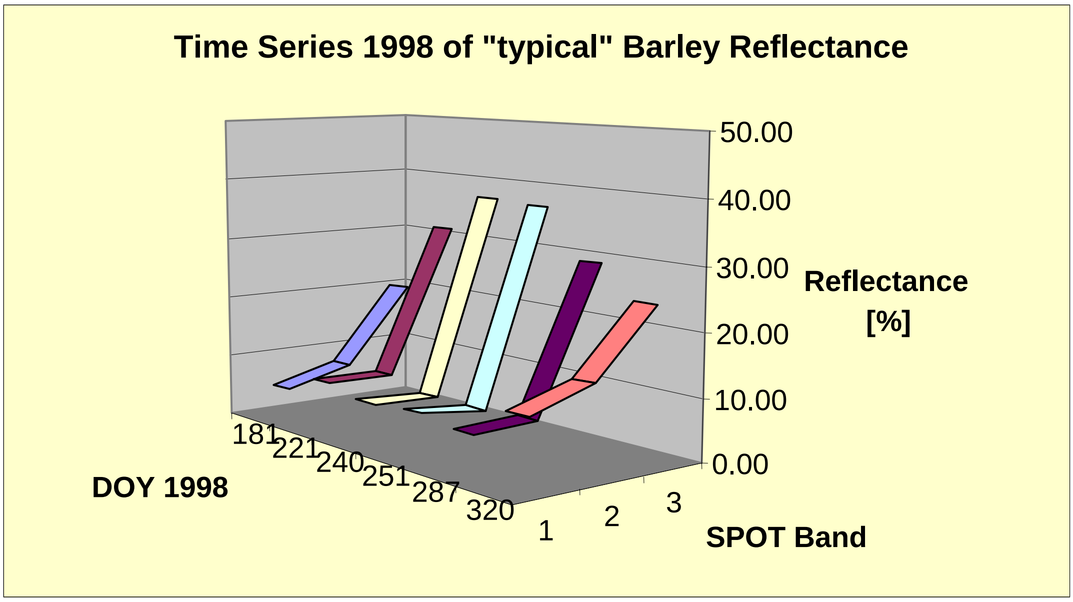


Figure 5.5: Typical spectral properties of barley in 1998 as observed by SPOT (see text for full explanation)

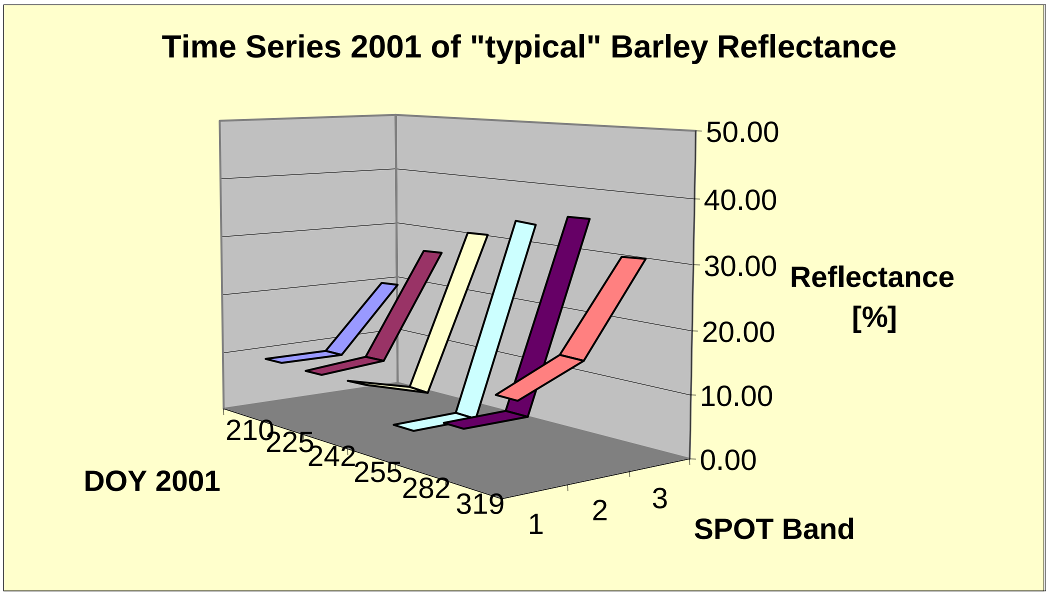
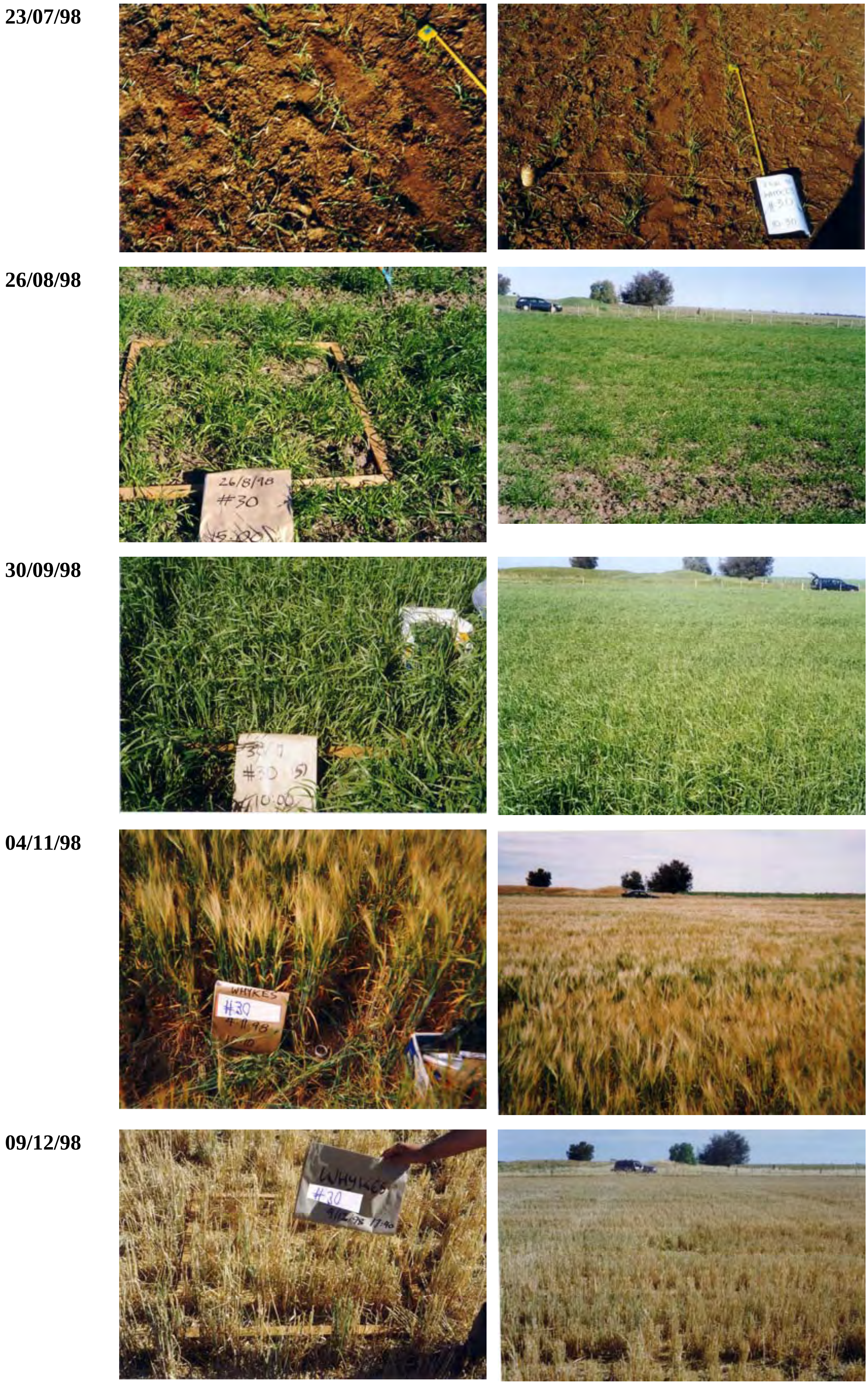


Figure 5.6: Typical spectral properties of barley in 2001 as observed by SPOT



Example 15-30 (Camp West) in 1998; Sowing date: 15/06/1998; Varity: Arapiles

Figure 5.7: Typical barley field throughout the crop cycle 1998 (see text for full explanation)

Canola

Canola developed lush green biomass throughout the crop season, which consequently was reflected in the canola crop signature in both years, 1998 and 2001. In 1998, the highest mean reflectance value (band 3, 47%) from all five crop types was observed in canola on DOY 240. Again a temporal shift was observed between the data from 1998 and 2001. Figure 5.8 and Figure 5.9 show SPOT spectral properties of canola in 1998 and 2001. Figure 5.10 illustrates a selected canola field in 1998.

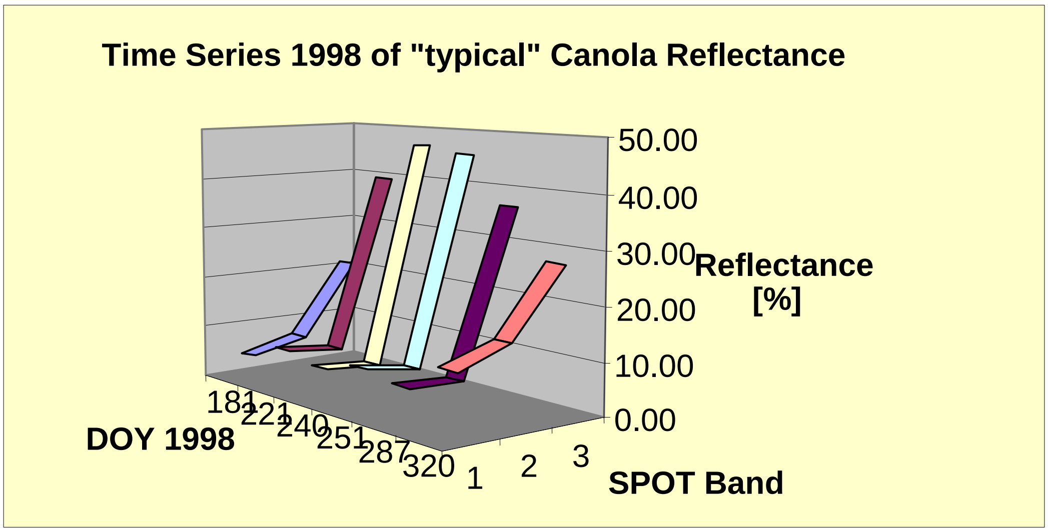


Figure 5.8: Typical spectral properties of canola in 1998 as observed by SPOT

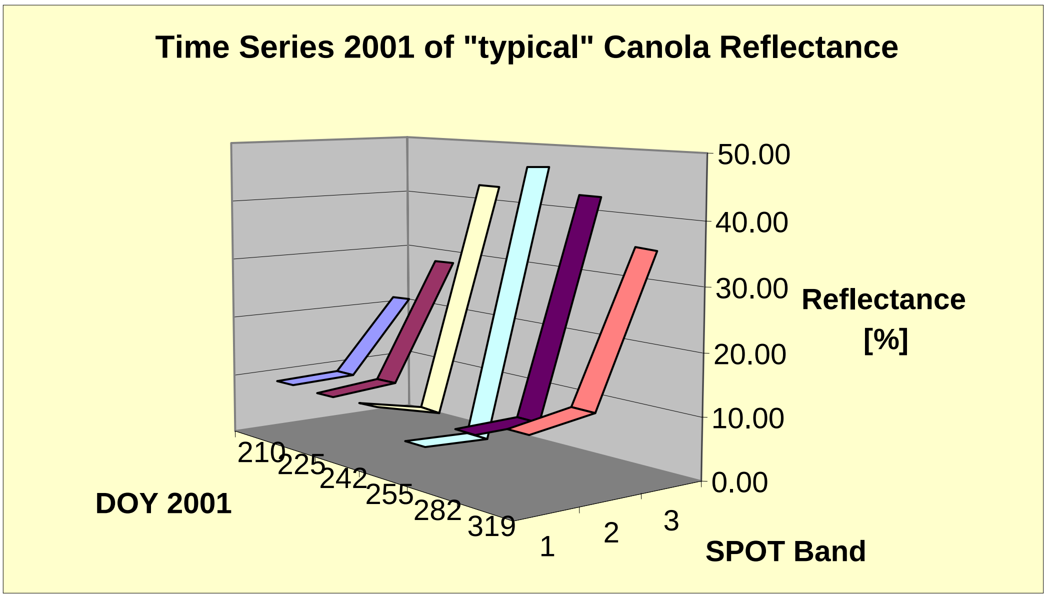


Figure 5.9: Typical spectral properties of canola in 2001 as observed by SPOT

19/6/98 (left) and 22/7/98 (right)

25/8/98

29/9/98

3/11/98

9/12/98

Example Weir Paddock 1998; Sowing date: 19/05/98; Varity: Dunkeld

Figure 5.10 Typical canola field throughout the crop cycle 1998

Chickpeas

In 1998 chickpeas developed full canopy ground cover later (DOY 320) than the other crop types under investigation. This was also observed in the time series of the SPOT data, with a steady increase into a typical vegetation spectrum. A similar pattern was observed in 2001, however once again a temporal shift was observed. Figure 5.11 and Figure 5.12 show the SPOT spectral properties of 1998 and 2001, Figure 5.13 shows chickpea photographs in 1998.

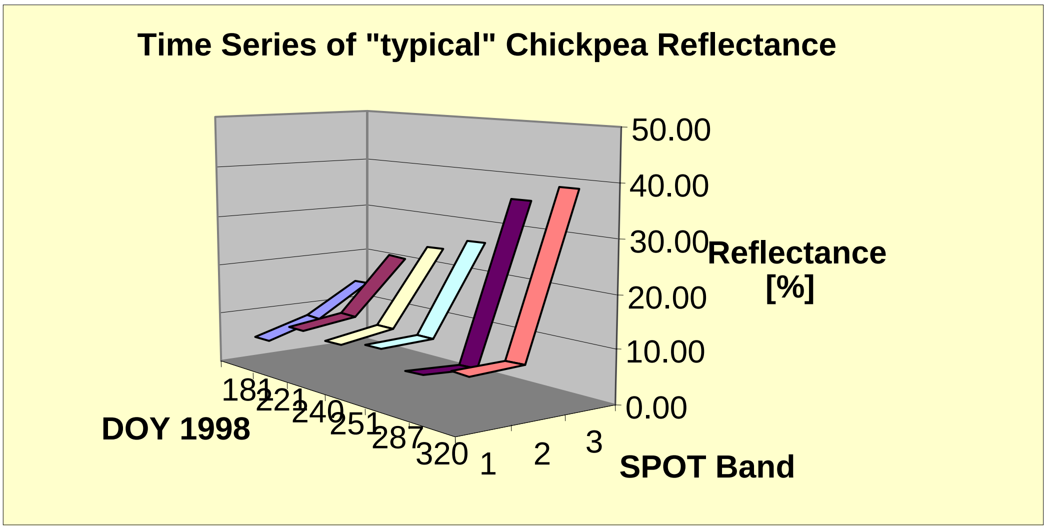


Figure 5.11: Typical spectral properties of chickpeas in 1998 as observed by SPOT

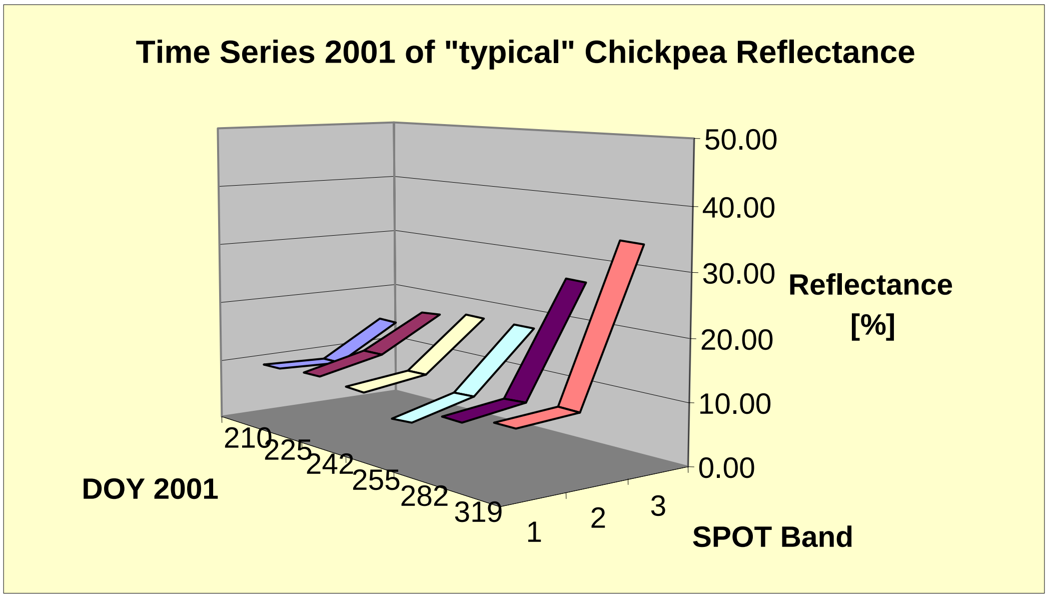


Figure 5.12: Typical spectral properties of chickpeas in 2001 as observed by SPOT

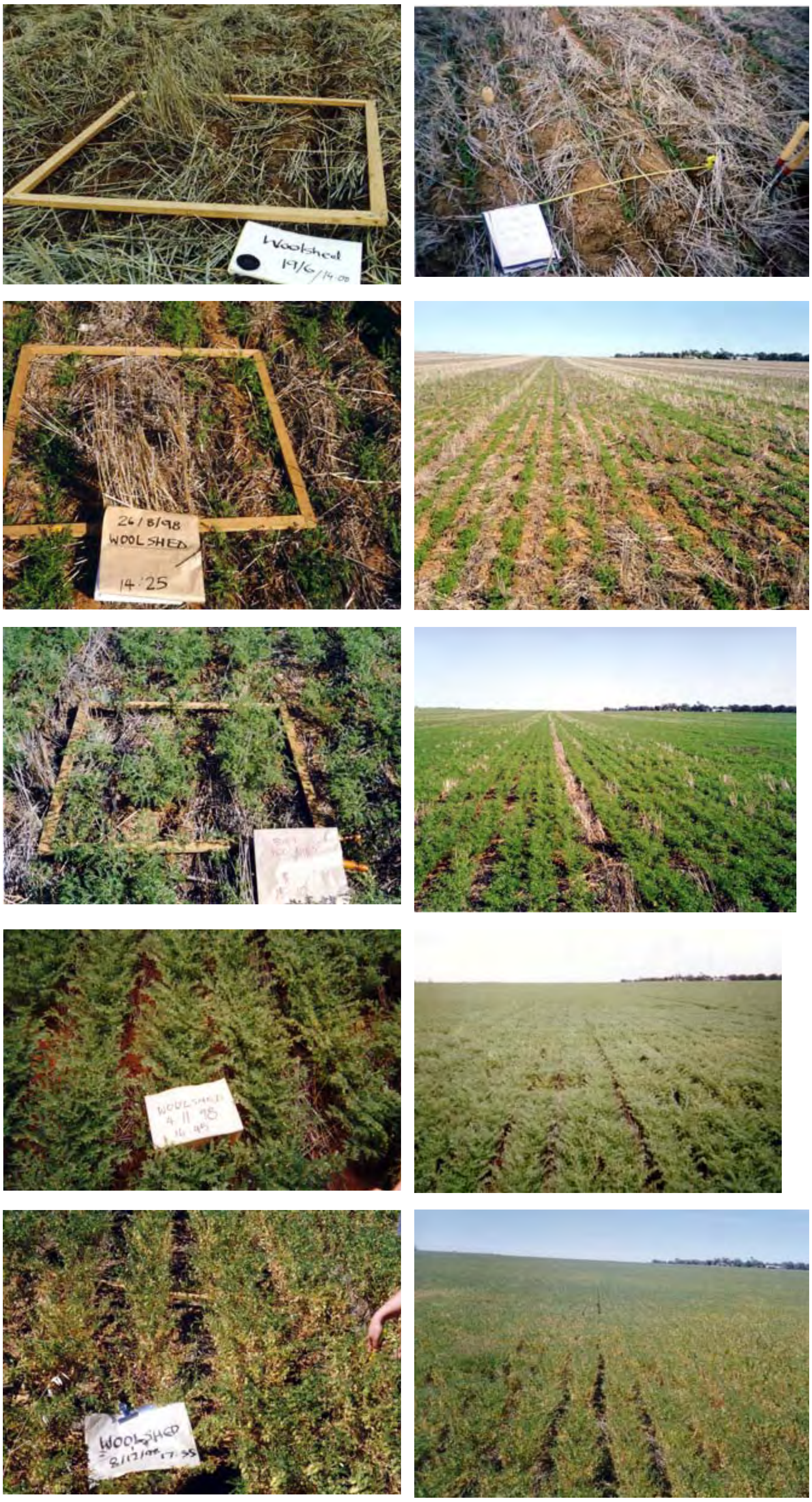
19/6/98 (left) and 23/7/98 (right)

26/8/98

30/9/98

4/11/98

8/12/98



Example Woolshed; Sowing date: 27/05/98; Varity: Amethyst

Figure 5.13 Typical chickpea field throughout the crop cycle 1998

Lentils

Lentil vegetation, like chickpeas, started developing ground cover later in the season than the other crops. Hence the observed signature reflected this, with a mean maximum in band 3 reached on DOY 287 (39%). The 2001 data showed a similar pattern with a temporal delay. Figure 5.14 and Figure 5.15 show the SPOT spectral properties of 1998 and 2001 while Figure 5.16 documents a lentil field throughout the 1998 crop season.

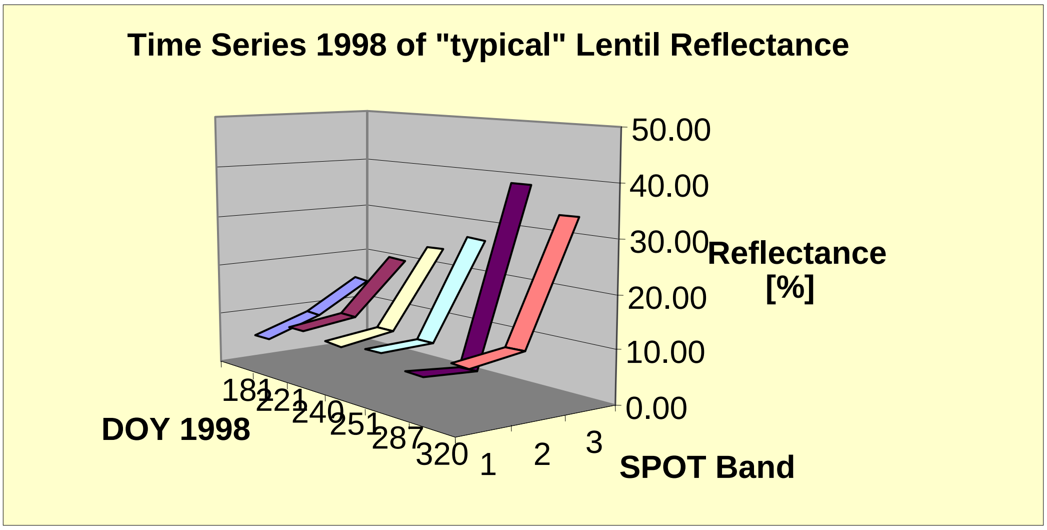


Figure 5.14: Typical spectral properties of lentil in 1998 as observed by SPOT

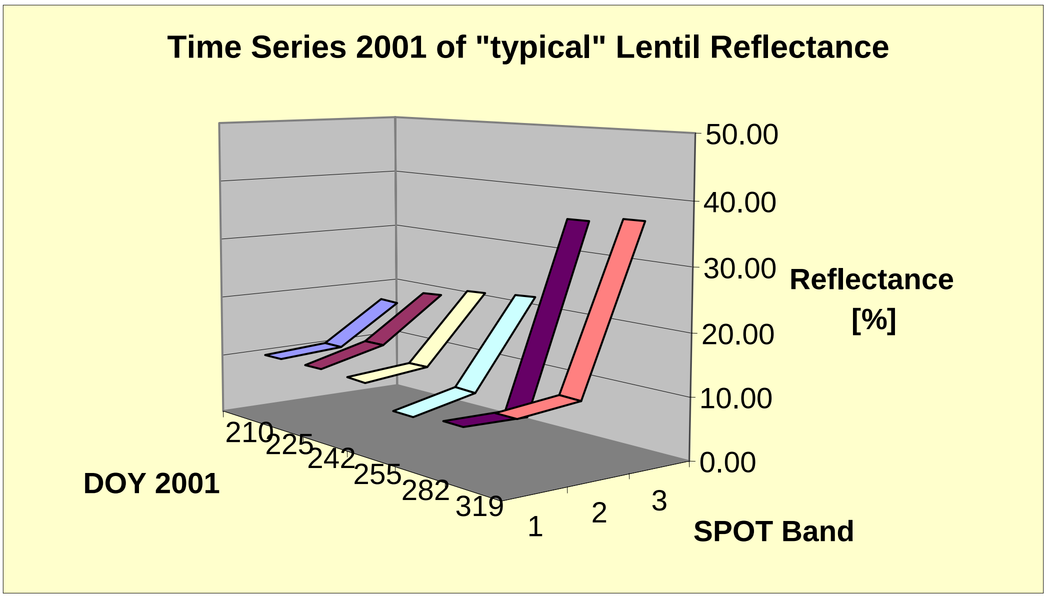


Figure 5.15: Typical spectral properties of lentil in 2001 as observed by SPOT

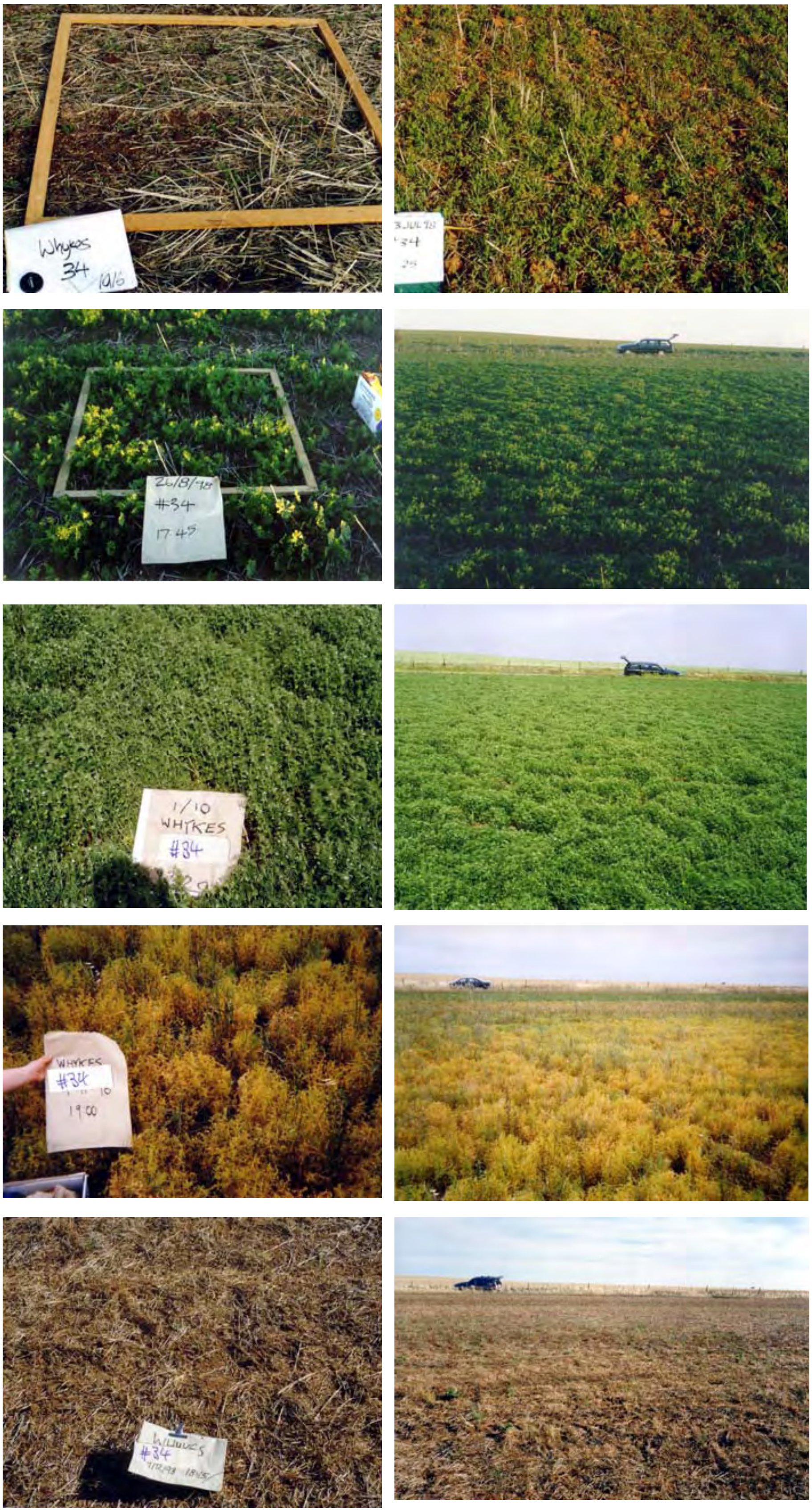
19/6/98 (left) and 23/7/98 (right)

26/8/98

1/10/98

4/11/98

9/12/98



Example 15- 34; Sowing date: 19/05/98; Varity: Digger

Figure 5.16 Typical lentil field throughout the crop cycle 1998

Wheat

The spectral properties of wheat were similar to the ones observed in barley in both years 1998 and 2001; only on DOY 320/ 319 the reflectance in the near infrared band was approximately 3% lower in wheat than in barley. Figure 5.17 and Figure 5.18 show the SPOT spectral properties of 1998 and 2001. Figure 5.19 includes photographs of the wheat crop development in 1998.

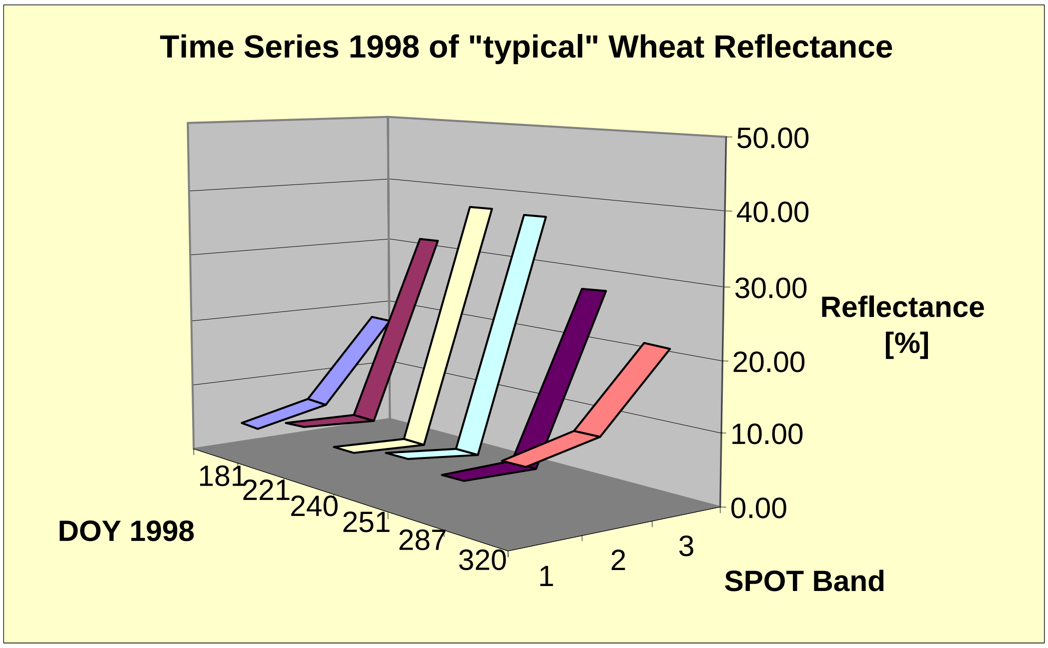


Figure 5.17: Typical spectral properties of wheat in 1998 as observed by SPOT

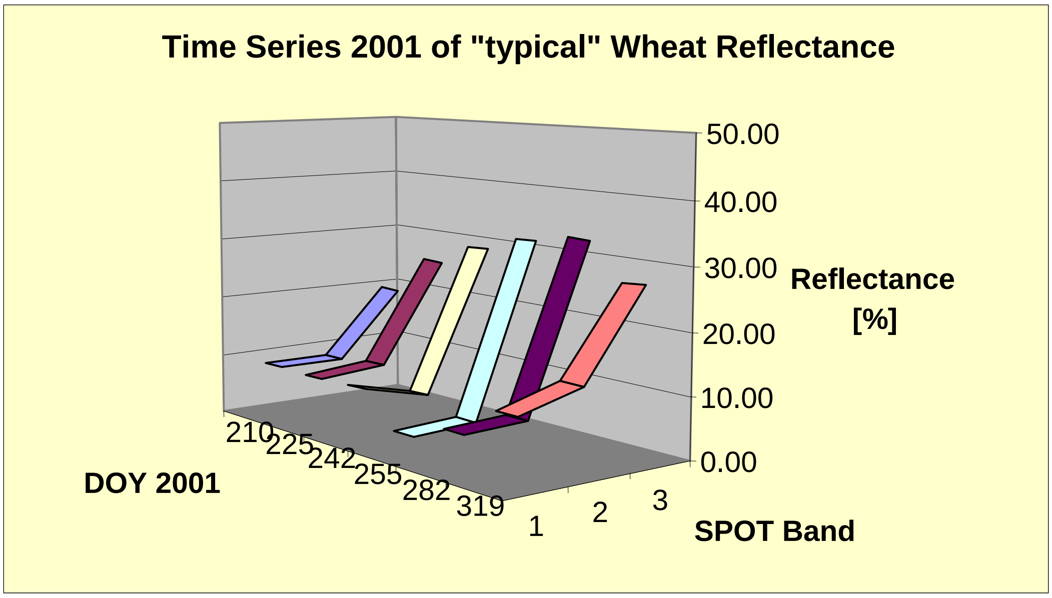
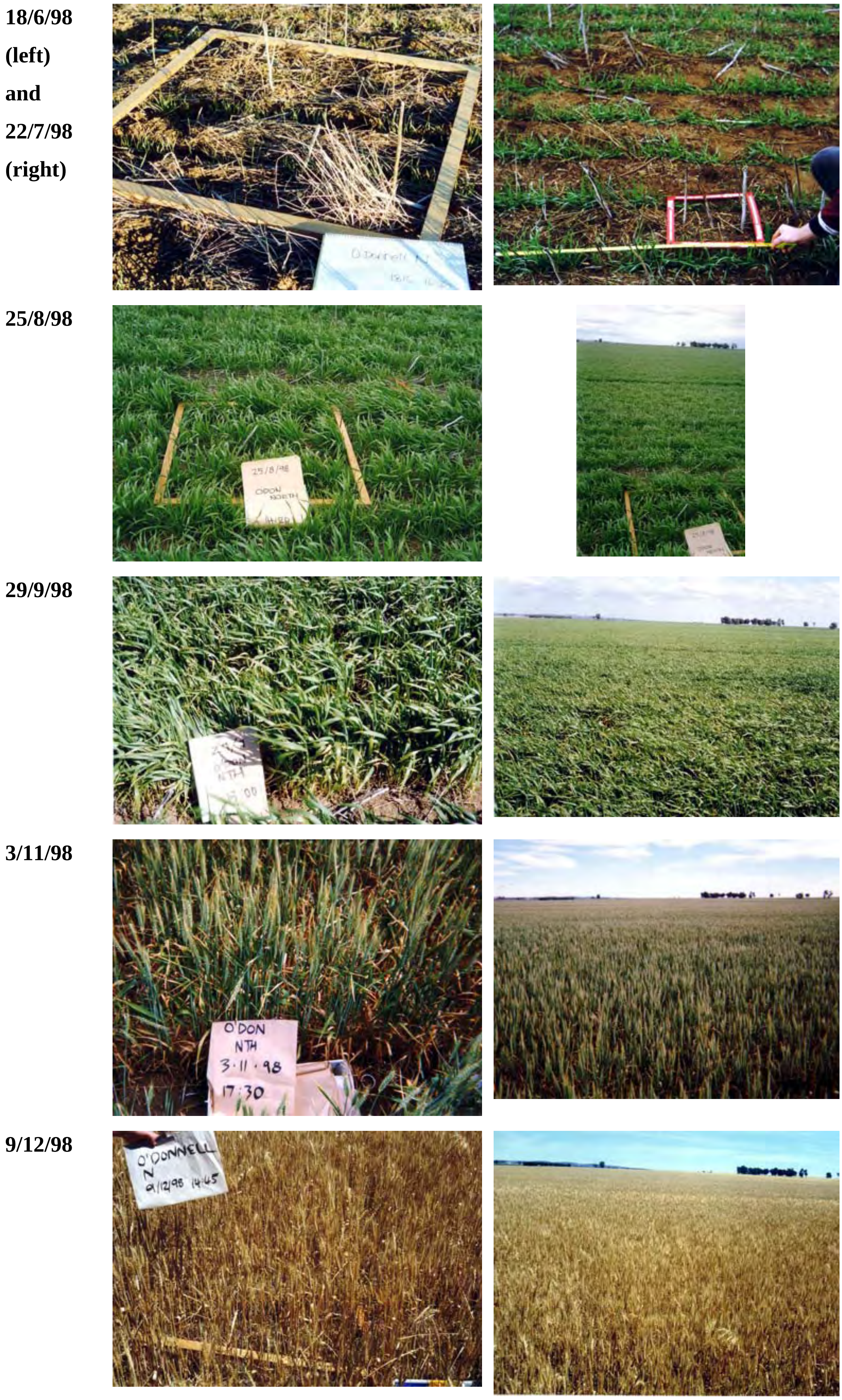


Figure 5.18: Typical spectral properties of wheat in 2001 as observed by SPOT



Example O'Donnel North Paddock 1998; Sowing date: 21/05/98; Varity: Goldmark

Figure 5.19 Typical wheat field throughout the crop cycle 1998

Comparison of the five crop types

When the SPOT satellite data were plotted as time series throughout the crop season, it was observed that as early as the 30/6 (DOY 181) chickpeas and lentils could be differentiated from barley, wheat and canola (NDVI). In 1998, chickpea and lentils were comparatively similar throughout the season, but could be differentiated on DOY 320, as chickpeas were still more photosynthetically active (2 % lower reflection in band 2, 5% higher in band 3- and hence a higher NDVI value) at this stage than lentils. In 2001 the differentiation between lentils and chickpeas would have to occur on DOY 282 (4% difference) or possibly DOY 255. Canola and wheat had very similar NDVI values throughout the season, however in both years canola's reflectance values in band 3 was approximately 10% higher between August and October (DOY 221- 287) than wheat. Wheat and barley had very similar reflectance values in band 3; however, wheat had 3% less reflectance than barley in band 1 and 2 in the middle of November (DOY 319, 320).

In figures 5.20 – 5.25 time series of all crop types were compared to assist in the understanding of the spectral behaviour and hence in the development of crop discrimination models. Figures for both years, 1998 and 2001 were produced.

The reflectance in band 1 only fluctuated approximately 2% throughout the season; only at the end of the season did reflectance values increase by approximately 4% due to the senescence of the crops. However, on DOY 255 in the 2001 data the reflectance for all crops was reduced by 2-4%. A similar 2-4 % reduced reflectance was also observed in the invariant target data of DOY 255 (see Figure 4.23 in Chapter 4). This was most likely due to the radiometric and atmospheric correction for DOY 255 being difficult despite careful attention to detail. Figures 5.20 and 5.21 show the reflectance in band 1 of all crop types and their respective development throughout the seasons 1998 and 2001.

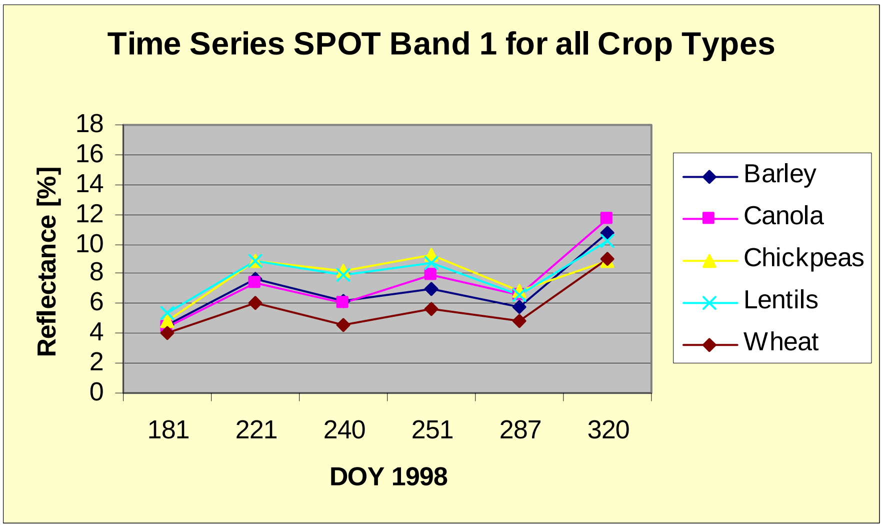


Figure 5.20 Time series 1998 band 1 for all crop types (end Jun-mid Nov) (see text for full explanation)

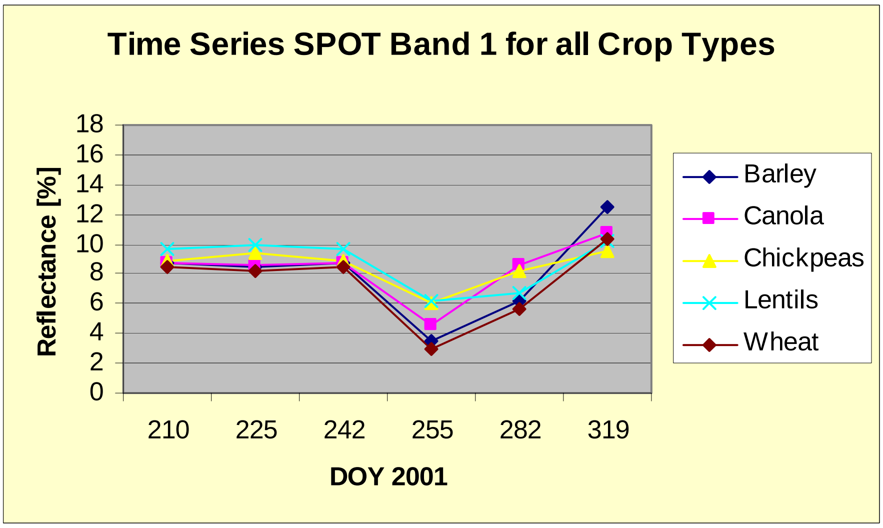


Figure 5.21 Time series 2001 band 1 for all crop types (end Jul-mid Nov)

In band 2 two groups were observed until DOY 255. Chickpeas and lentils reflected more red light than barley, canola and wheat. This was observed in both years. The reason for this was that barley, canola and wheat had more biomass earlier in the season, and therefore more red light was absorbed by the chlorophyll pigments in the plants. Canola was still more photosynthetically active on DOY 319 in 2001 than on DOY 320 in 1998. Chickpeas performed only moderately in 2001; sowing occurred later in 2001 than in 1998, and chickpeas never reached their full potential in the 2001 season. Figure 5.22 and 5.23 show the SPOT time series of all crops in band 2.

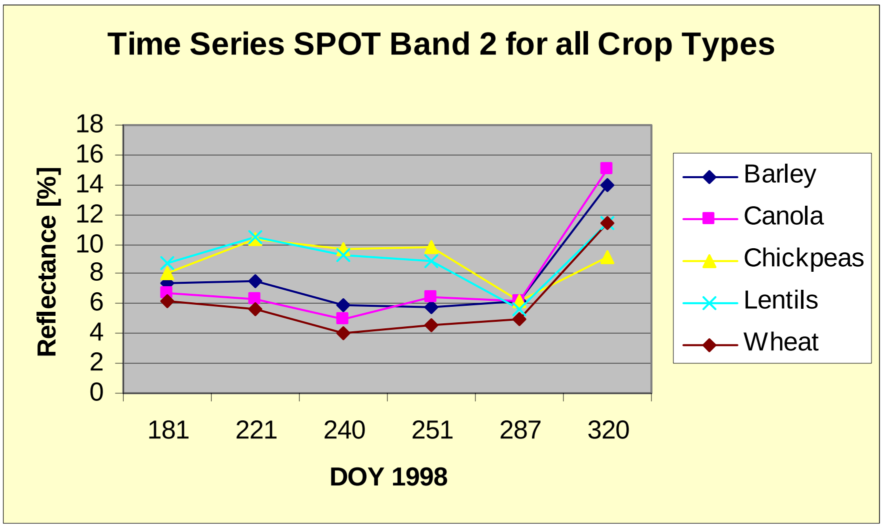


Figure 5.22 Time series 1998 band 2 for all crop types (end Jun-mid Nov)

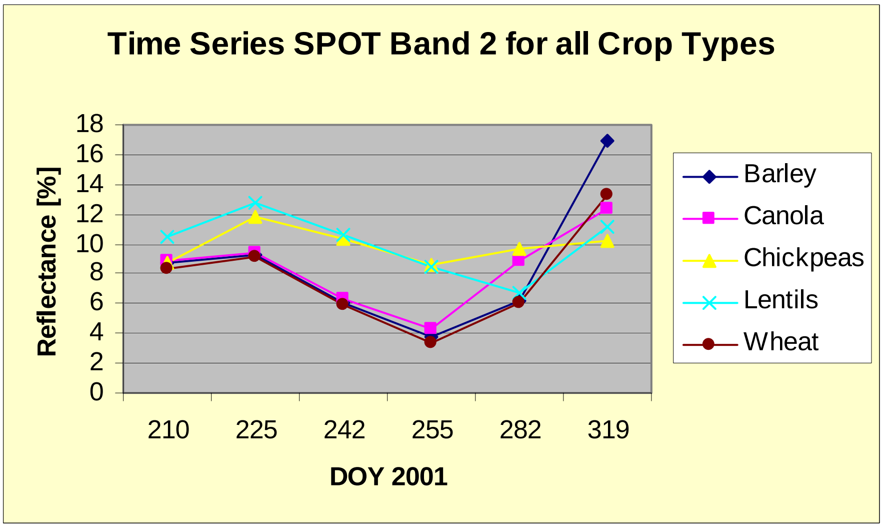


Figure 5.23 Time series 2001 band 2 for all crop types (end Jul-mid Nov)

In band 3 three distinct groups were observed in both years. Canola had the most biomass and hence the highest reflection in band 3. Wheat and barley appeared very similar in band 3. Least green biomass was present on chickpea and lentil fields until DOY 255. Towards the end of the 1998 season, chickpeas and lentils were clearly more photosynthetically active than barley, canola and wheat. Lentils were very similar in 1998 and 2001, while the reflectance in band 3 was approximately 4% higher in 1998 than in 2001 in chickpeas. The time series of SPOT band 3 data of all crops were presented in Figure 5.24 and 5.25.

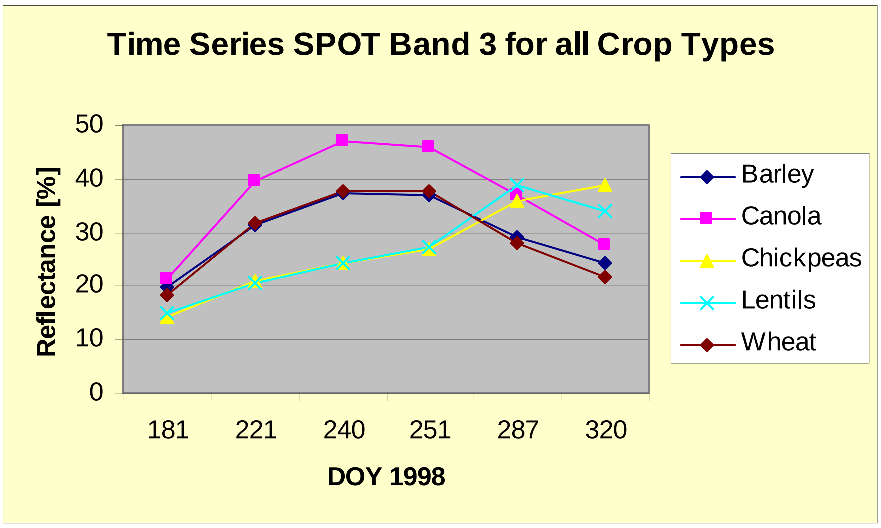


Figure 5.24 Time series 1998 band 3 for all crop types (end Jun-mid Nov)

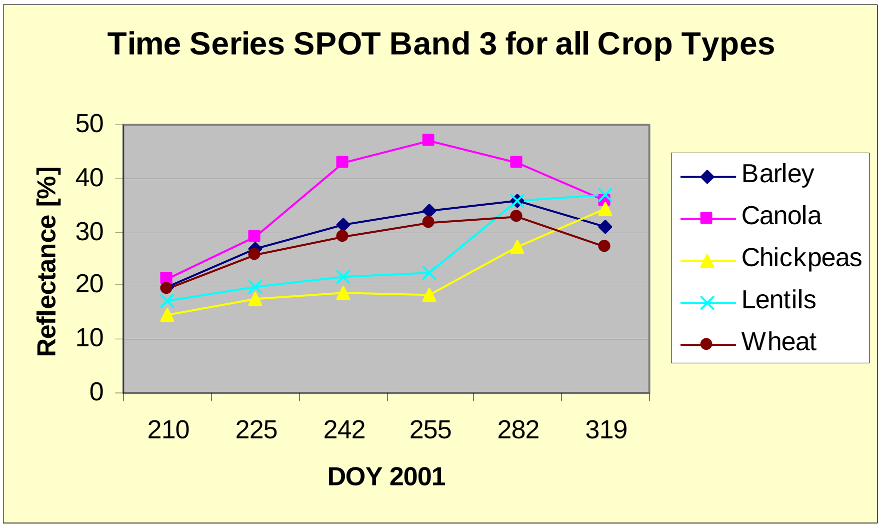


Figure 5.25 Time series 2001 band 3 for all crop types (end Jul-mid Nov)

The NDVI time series of both years was split in two groups; barley, canola and wheat were distinctly different to lentils and chickpeas. In 2001 the NDVI "curvature" of barley, canola and wheat was spread over a shorter time frame than in 1998. Figure 5.26 and 5.27 show the progressive development of the NDVI values per crop type in 1998 and 2001.

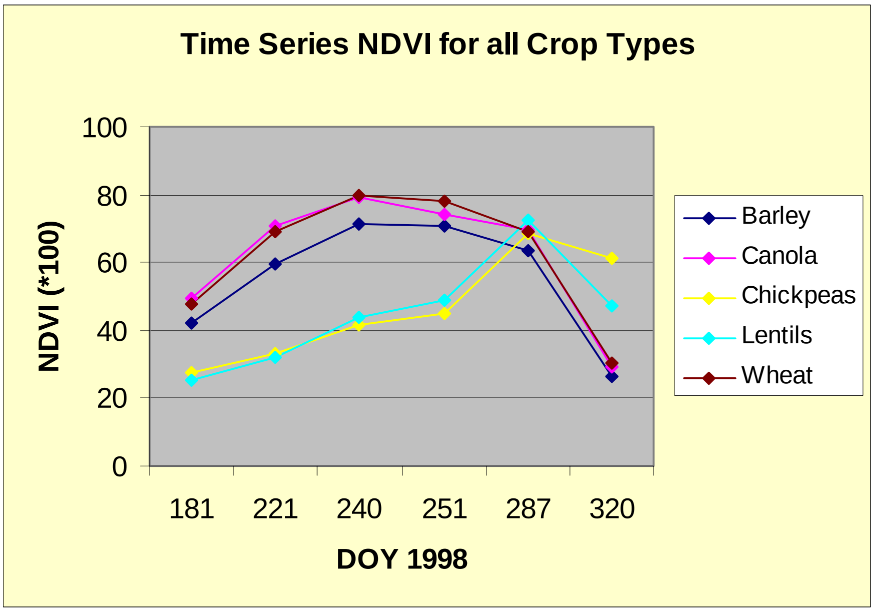


Figure 5.26 Time series 1998 NDVI for all crop types (end Jun-mid Nov)

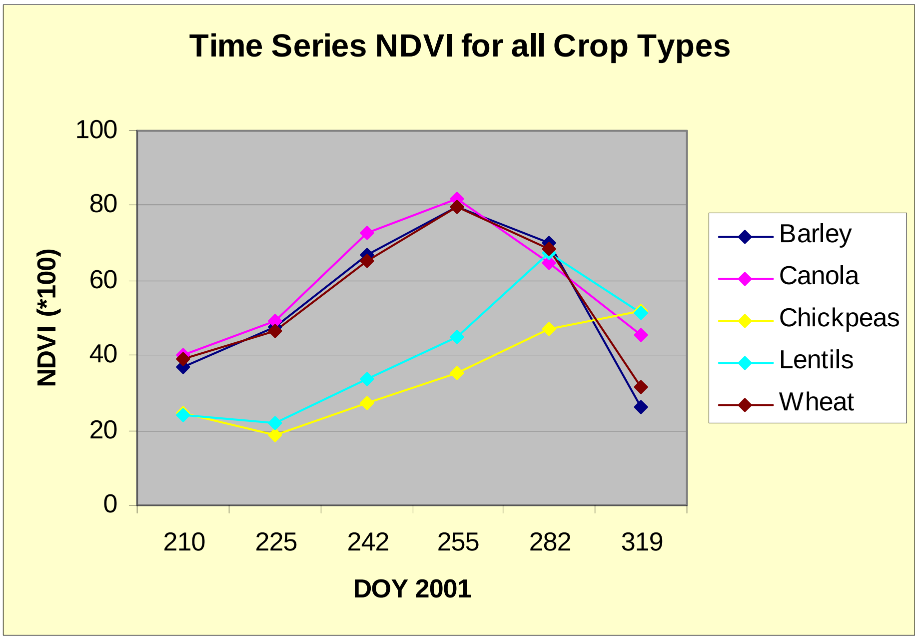
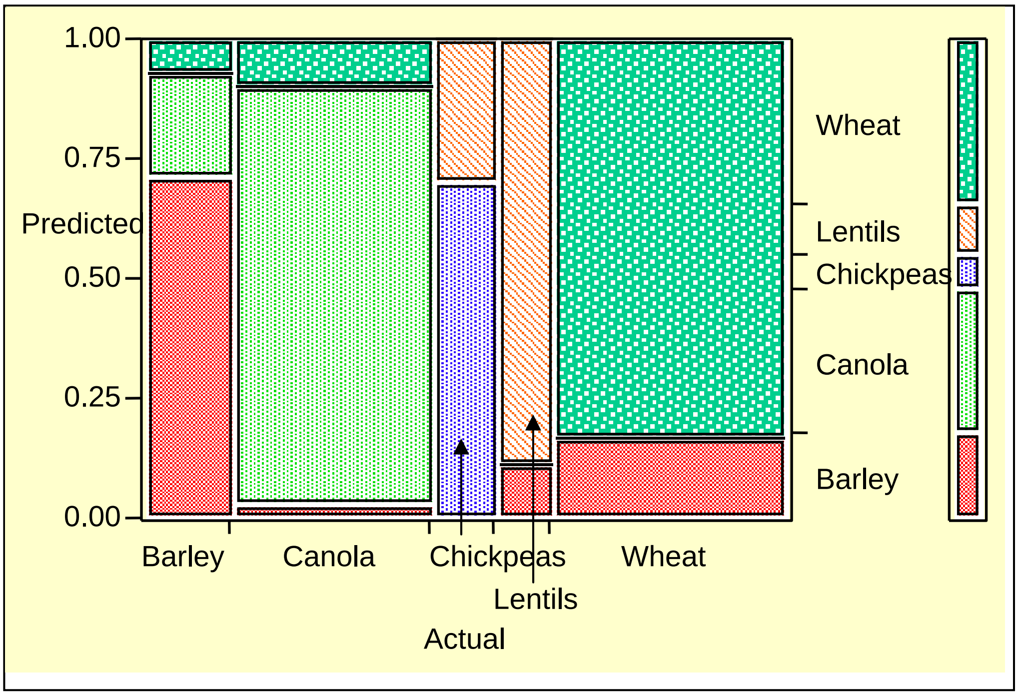


Figure 5.27 Time series 2001 NDVI for all crop types (end Jul-mid Nov)

5.3.2 Crop type discrimination results

Single Date Models

To illustrate the method discussed in 5.2.5, a detailed example of the results of Model IV of DOY 240 is presented. Figure 5.28 shows the mosaic graph, Table 5.1 the corresponding contingency table of actual versus predicted classes and Table 5.2 gives model details. Overall model IV for DOY 240 had an Rsquare (U) of 0.6570 (Table 5.2).



Mosaic plot of Model IV-DOY 240: the height of the columns represents predicted percentile accuracies, while the width of the columns represents actual (percentile) crop types; this is equivalent to the bar on the right hand side of the graph. In this model, ten of 14 barley fields were correctly classified (71.43%), with some confusion with canola (3 fields, 21.43 %) and wheat (1 field, 7.14%). 27 canola fields were classified correctly (87.10%), confusion occurred with the classes barley (1 field, 3.23%) and wheat (3 fields, 9.68%). 70% of chickpea paddocks were identified accurately (7 fields), with wrong assignment to 3 lentil fields (30%). Eight lentil fields were identified properly (88.89%), one field was confused with barley. The majority of the wheat fields were classified accurately (30 fields, 83.33%), with some (expected) confusion with barley (6 fields, 16.67%).

Figure 5.28: Contingency analysis of predicted by actual mosaic plot for Model IV, DOY 240

Table 5.1: Contingency Table- Actual by Predicted for Model IV, DOY 240

Count Total % Col % Row %	Barley	Canola	Chickpeas	Lentils	Wheat	Actual
Barley	10 10.00 55.56 71.43	3 3.00 10.00 21.43	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 1.00 2.94 7.14	14 14.00
Canola	1 1.00 5.56 3.23	27 27.00 90.00 87.10	0 0.00 0.00 0.00	0 0.00 0.00 0.00	3 3.00 8.82 9.68	31 31.00
Chickpeas	0 0.00 0.00 0.00	0 0.00 0.00 0.00	7 7.00 100.00 70.00	3 3.00 27.27 30.00	0 0.00 0.00 0.00	10 10.00
Lentils	1 1.00 5.56 11.11	0 0.00 0.00 0.00	0 0.00 0.00 0.00	8 8.00 72.73 88.89	0 0.00 0.00 0.00	9 9.00
Wheat	6 6.00 33.33 16.67	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	30 30.00 88.24 83.33	36 36.00
Predicted	18 18.00	30 30.00	7 7.00	11 11.00	34 34.00	100

Contingency Table of Model IV-DOY 240: In each field actual versus predicted parameters are presented in four rows of numbers. The first row gives the count of fields which were classified. The second row translates the count into Total %. The third row gives the percentage for the total column (Col %) and lastly, the fourth row give the percentage value classified (Row %).

Table 5.2: Model Tests for Model IV, DOY 240

Source	DF	-LogLike	RSquare (U)
Model	16	96.29631	0.6570
Error	80	50.26362	
C. Total	96	146.55993	
N	100		

Twenty-four single date Models were calculated (Model I-IV * 6 acquisition dates) and from the contingency tables actual versus predicted accuracy percentages were obtained for each crop type under investigation.

Figures 5.29- 5.34 summarize the results for each acquisition date. The data tables are in Appendix D.

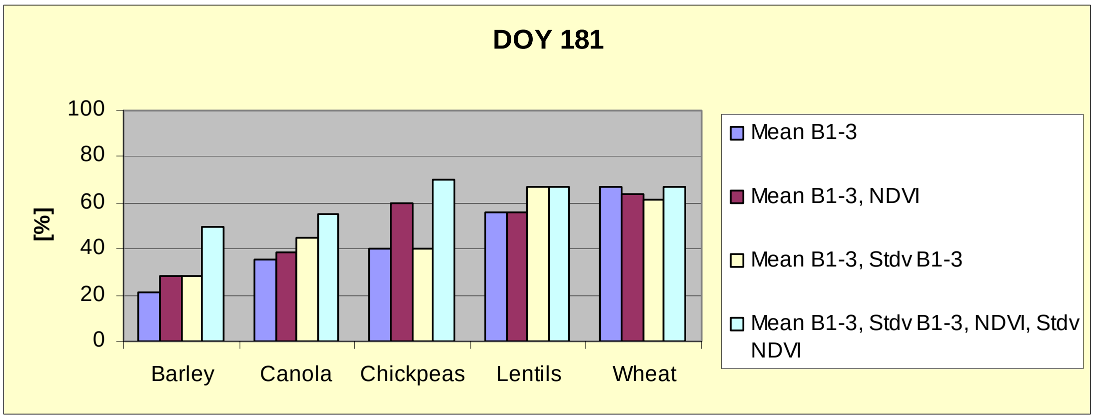


Figure 5.29: Discriminant function analysis result for model I-IV by crop type, DOY 181

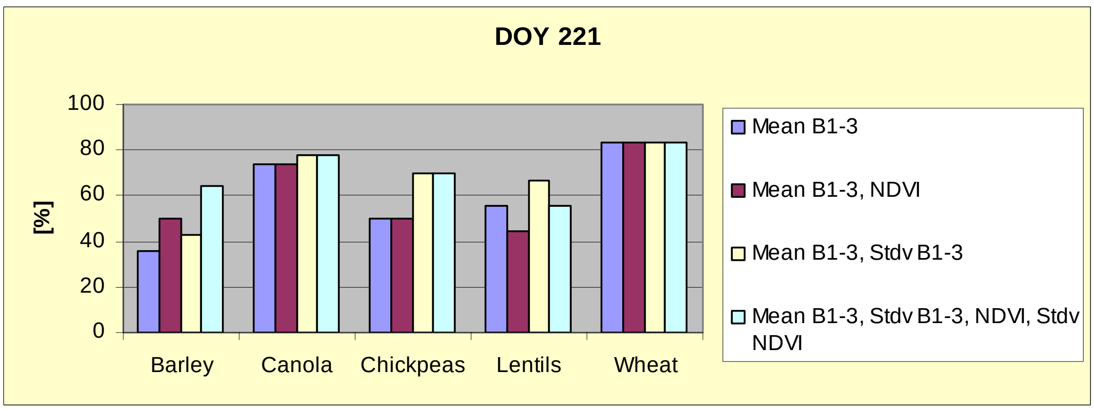


Figure 5.30: Discriminant function analysis result for model I-IV by crop type, DOY 221

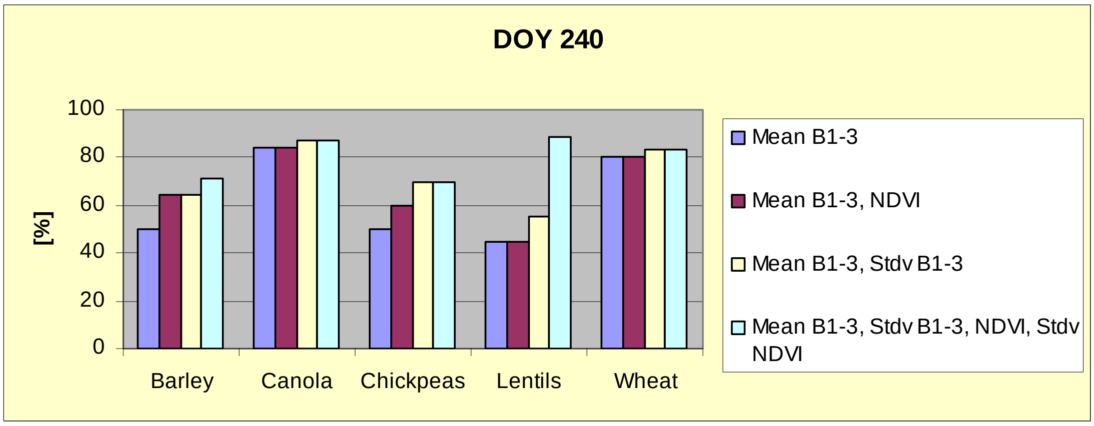


Figure 5.31: Discriminant function analysis result for model I-IV by crop type, DOY 240

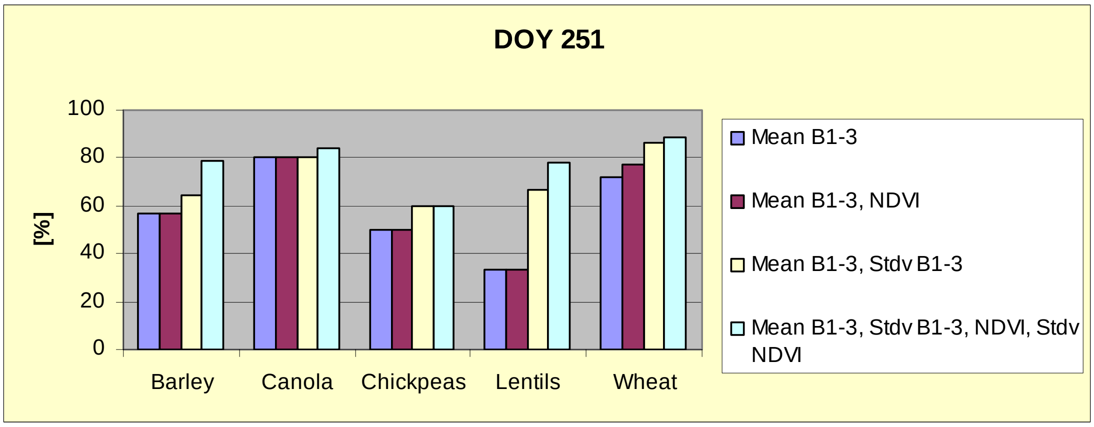


Figure 5.32: Discriminant function analysis result for model I-IV by crop type, DOY 251

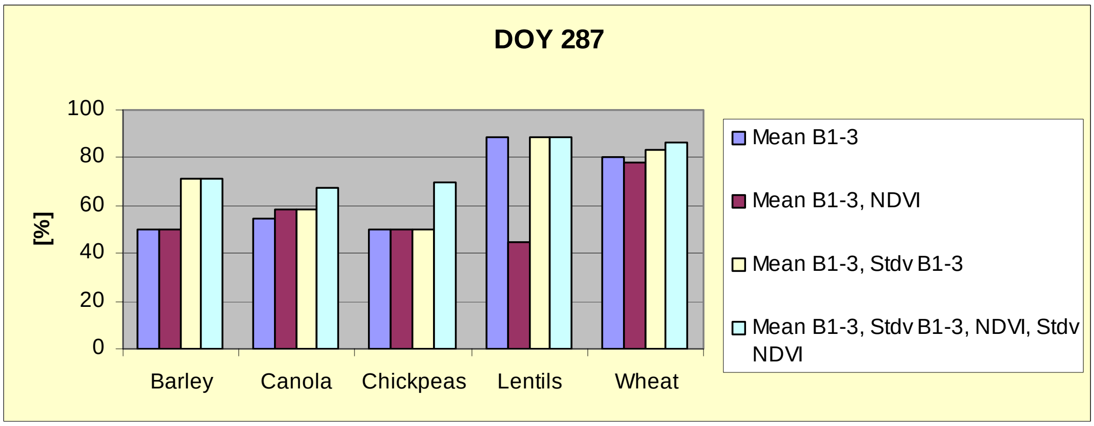


Figure 5.33: Discriminant function analysis result for model I-IV by crop type, DOY 287

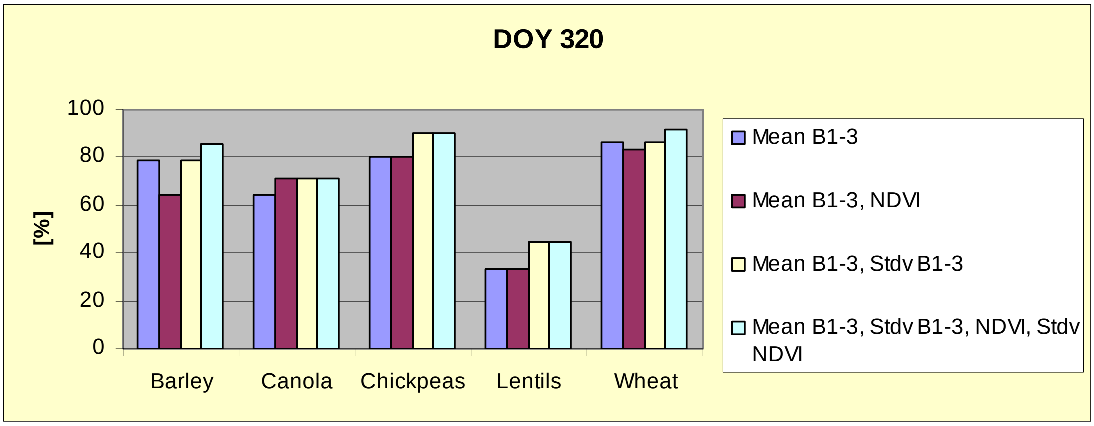


Figure 5.34: Discriminant function analysis result for model I-IV by crop type, DOY 320

Model IV was the best performed for all crop types, however at different accuracy levels depending on crop type. The range of the best results was from 85.71% for barley to 91.67% for wheat. Details on the best accuracy results for crop type discrimination found in this study (per crop type with their respective acquisition date) are given in Table 5.3.

Table 5.3: Best results of single date models in 1998 (per crop type)

Crop Type	Model	Accuracy	Comment
Barley	IV	85.71%	On DOY 320
Canola	IV	87.10%	On DOY 240
Chickpeas	III & IV	90.00%	On DOY 320
Lentils	IV	88.89%	On DOY 240
Wheat	IV	91.67%	On DOY 320

The best result (85.71%) for barley was obtained on DOY 320 with Model IV. For barley Model IV also performed well throughout the remainder of the season. Accuracy results of 87.10% and 83.87% respectively were obtained for canola in mid season (DOY 240, 251) with Model IV; having the standard deviations with the 3 SPOT bands improved accuracies until DOY 240. On DOY 320 the best result was obtained (90%) for chickpeas when the standard deviation was added (Model III and

IV). On DOY 181 adding the NDVI improved the results over 20%. When for lentil data the NDVI was added to Band 1-3 (Model II) the model was not improved. Adding the standard deviation (Model III and IV) however did improve the model on most dates. Best results were obtained on DOY 240 & 287 (both 88.89%); interestingly adding the NDVI to the 3 SPOT bands on DOY 287 created more confusion, hence the accuracy was only 44.44%. For wheat all four models performed strongly throughout the season, with the best result reached on DOY 320, Model IV (91.67%).

Conclusively it can be said that from the four models Model IV performed best in most cases. Early in the season (DOY 181) the classification accuracies were weaker, with the best result reaching just over 30%. Best results in the 1998 season were obtained on DOY 240 and 320 with an accuracy of over 60%. These results are found in Figure 5.35, showing the overall model result expressed in the Rsquare(U).

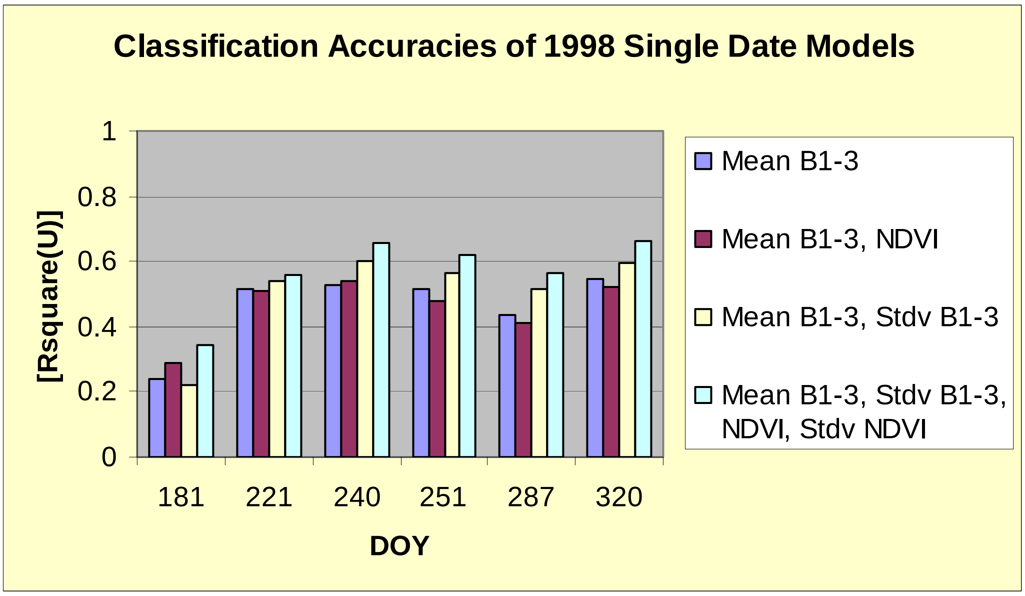


Figure 5.35: Overview of the 1998 Crop type discrimination model results (single date models)

Progressive Date Models

Twenty more models were calculated (Model I-IV for 5 dates, DOY 181 was already calculated and presented in 5.3.2, single date section). To simplify the discussion, the model was named by the last acquisition date; i.e. the model using information from DOY 181 & DOY 221 & DOY 240 & DOY 251 was called Model DOY 251.

Figures 5.36 to 5.40 summarize the results. Data tables are in Appendix E.

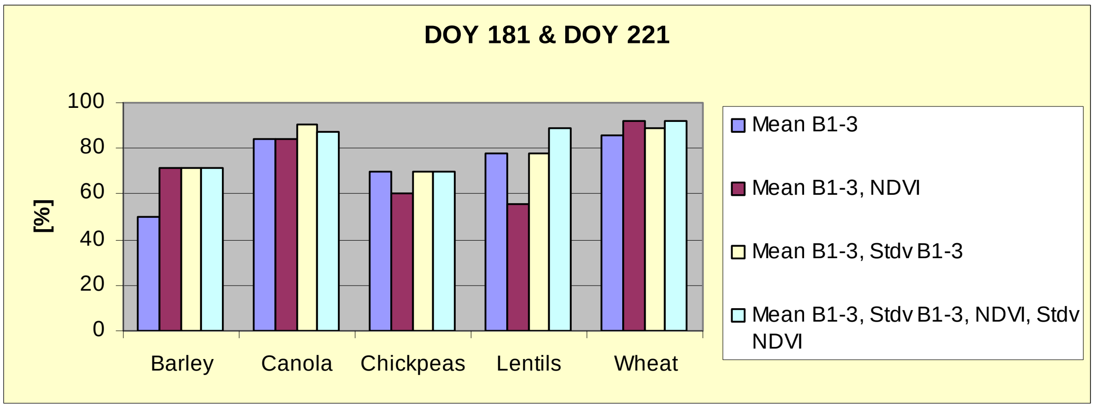


Figure 5.36: Discriminant function analysis result for model I-IV by crop type, until DOY 221, 1998

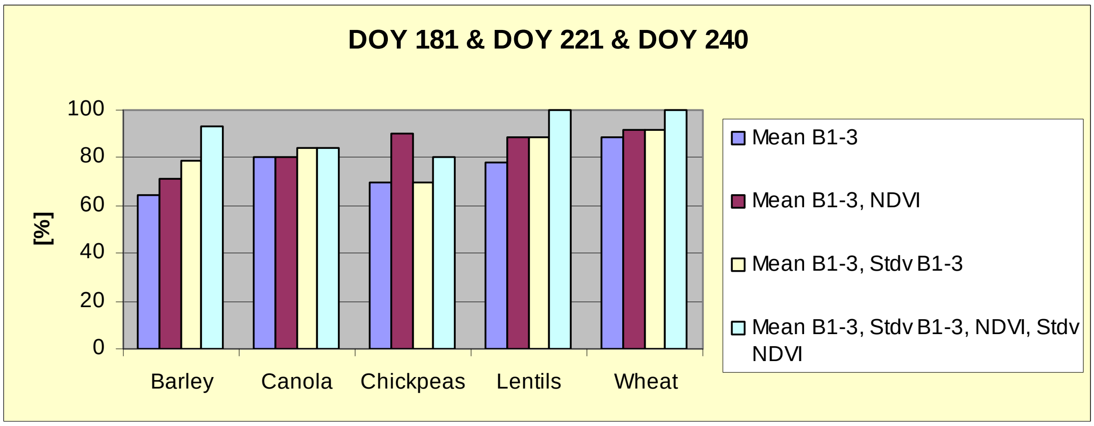


Figure 5.37: Discriminant function analysis result for model I-IV by crop type, until DOY 240, 1998

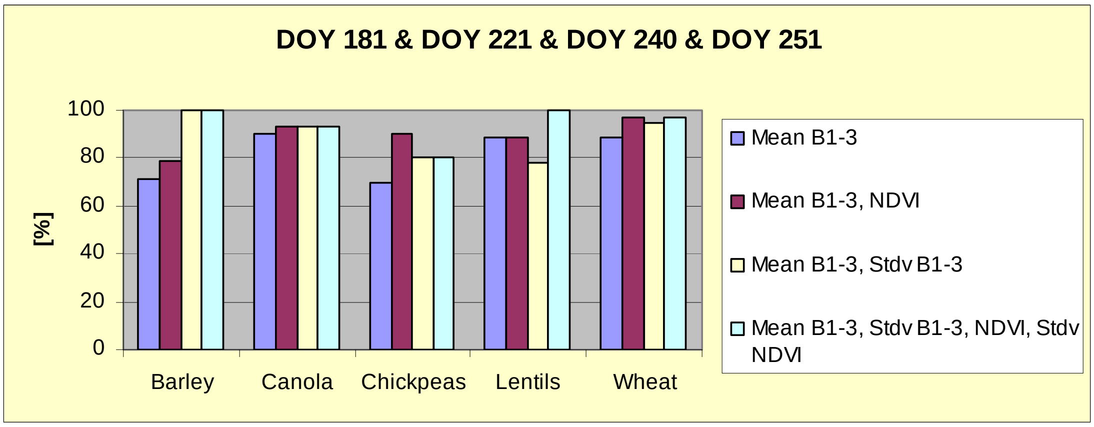


Figure 5.38: Discriminant function analysis result for model I-IV by crop type, until DOY 251, 1998

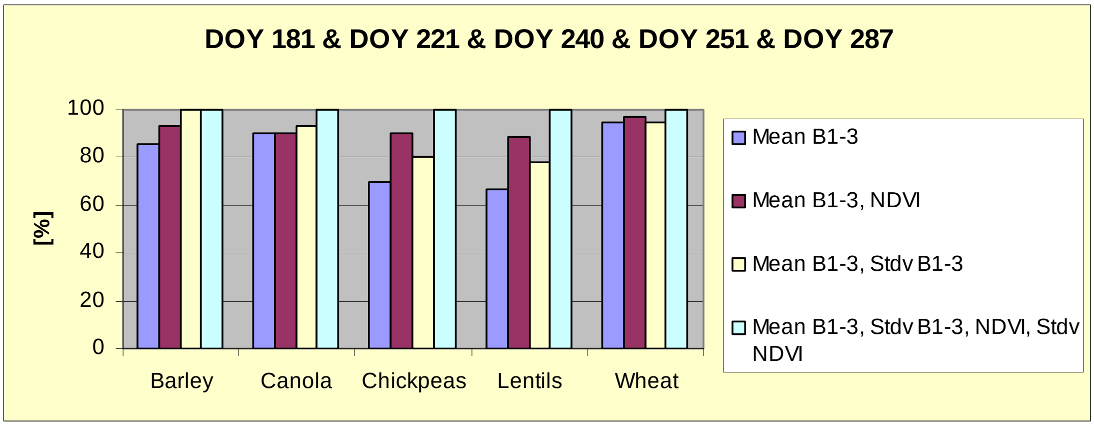


Figure 5.39: Discriminant function analysis result for model I-IV by crop type, until DOY 287, 1998

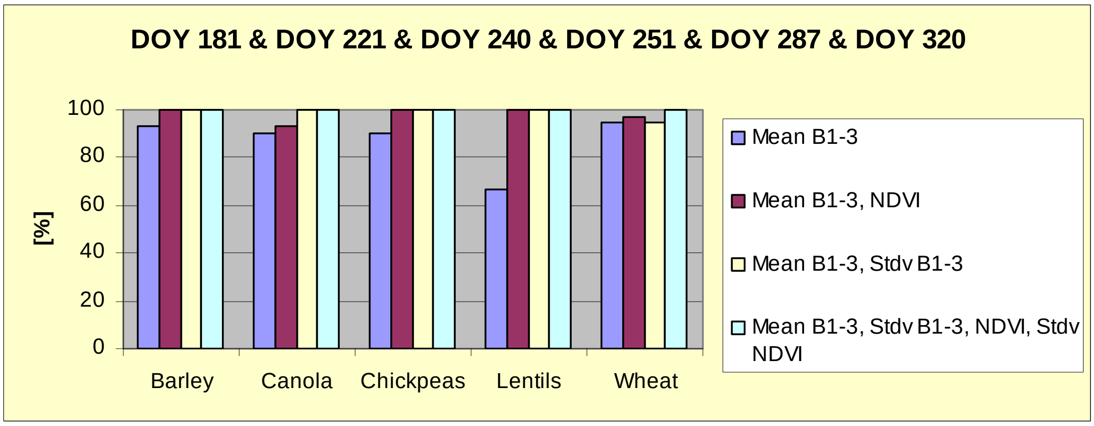


Figure 5.40: Discriminant function analysis result for model I-IV by crop type, until DOY 320, 1998

All crop types reached accuracies of 100%. Model IV performed strongest for all crops. Details of the best results and their respective acquisition date are listed in Table5.4.

Table 5.4: Best results of progressive date models in 1998 (per crop type)

Crop Type	Model	Accuracy	Comment
Barley	III & IV	100%	After incl. DOY 251
Canola	IV	100%	After incl. DOY 287
Chickpeas	IV	100%	After incl. DOY 287
Lentils	IV	100%	After incl. DOY 240
Wheat	IV	100%	After incl. DOY 240 (but excl. DOY 251)

In the progressive date models 100% of all barley fields were classified correctly in Model III and IV as early as DOY 251. Using the standard deviation improved the results. Canola was correctly classified from DOY 287 onwards (Model IV). Earlier in the season the standard deviation had slightly improved the results. Chickpeas were all correctly classified on DOY 287. After DOY 240 adding the NDVI improved the results. Lentils were accurately classified with Model IV as of DOY 240. On DOY 320 all models but Model I reached 100%. Wheat accuracies of 100% were reached from DOY 240 onwards (Model IV); on DOY 251 “only” 97.14% accuracy was obtained as one field was confused with barley (Model IV). The inclusion of the NDVI had improved the results.

Classification accuracies using discriminant function analysis were significantly improved when using information from multiple acquisition dates throughout the crop season. As early as DOY 240 accuracies well over 0.8 were obtained with Model IV. Accuracies of Rsquare (U) = 1 could be achieved as of October (DOY 287). The overall model accuracies (of the progressive date models), expressed in Rsquare (U) are presented in Figure 5.41.

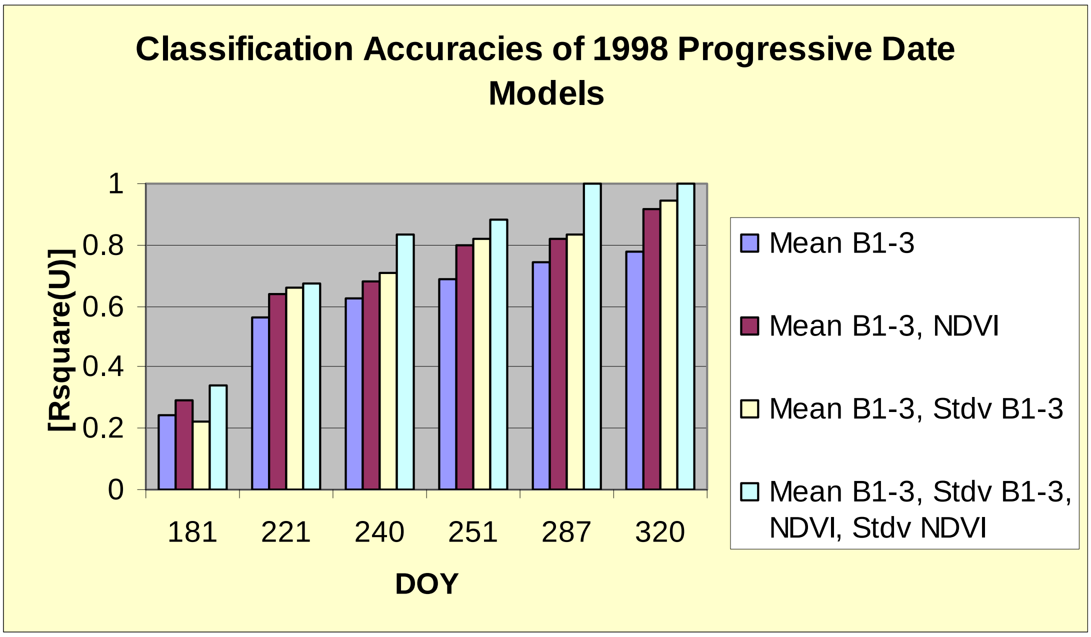


Figure 5.41: Overview of the 1998 Crop type discrimination model results (progressive date models)

Note that DOY 181 was a single date event and was identical to the data previously presented in Figure 5.35.

Comparison of the 1998 and 2001 results

From the 2001 data the same single date and progressive date models I- IV were calculated. The model performances were summarized in Figure 5.42 and 5.43. The data tables can be found in Appendix D and E.

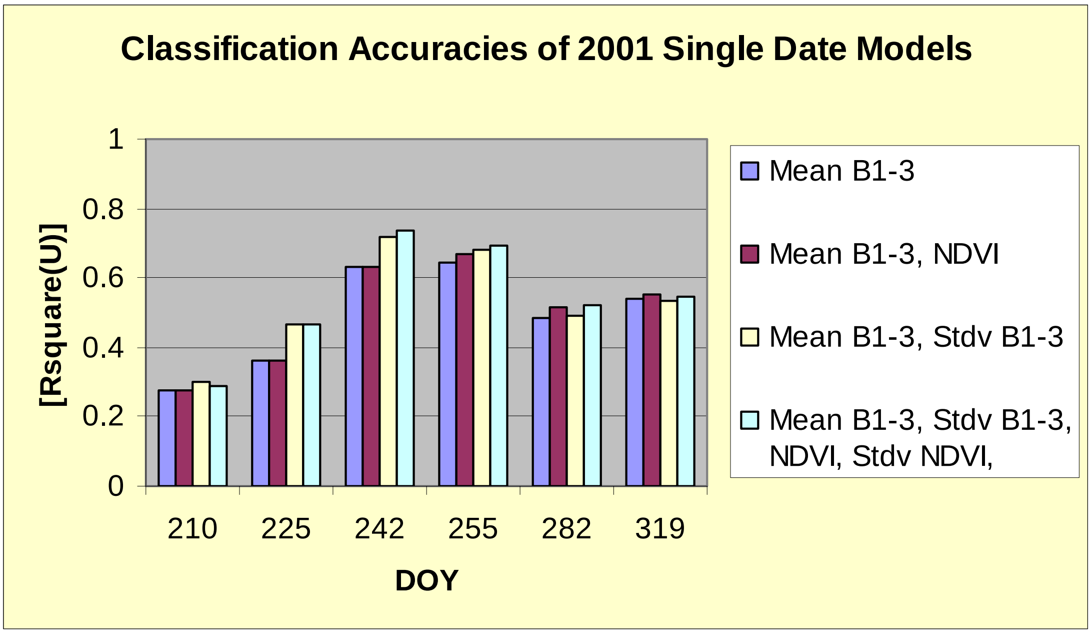


Figure 5.42: Overview of the 2001 Crop type discrimination model results (single date models)

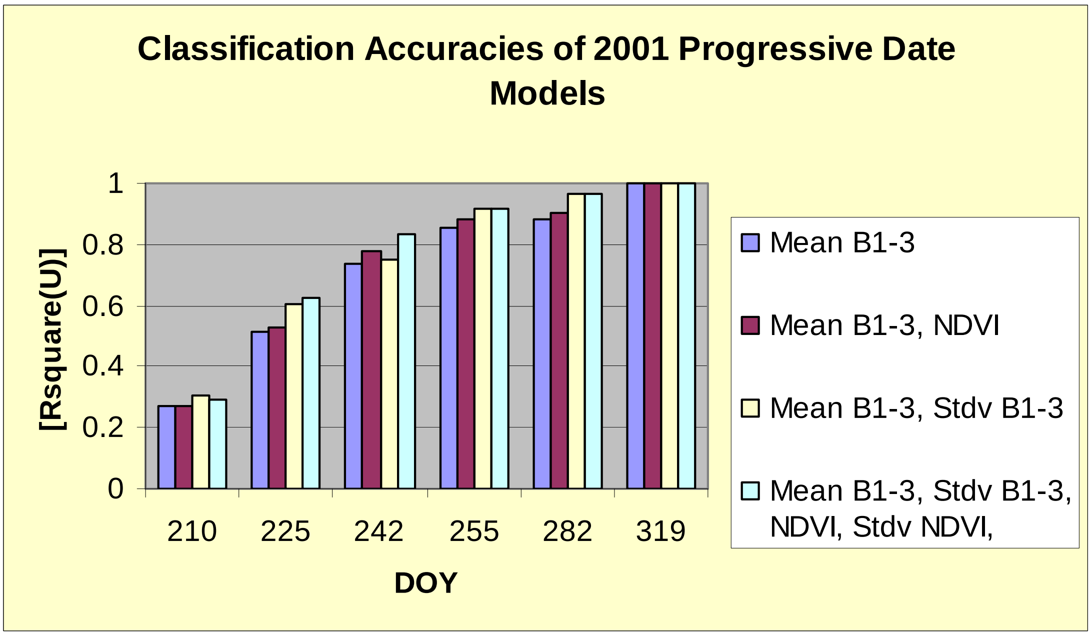


Figure 5.43: Overview of the 2001 Crop type discrimination model results (progressive date models)

The difference between the Rsquare (U) values of models was calculated between the year 1998 and 2001; the calculations were computed for the single date model and the progressive date model. The data tables are found in Appendix F. It was found that the difference in model results between the two years was mostly under 0.05 (with the very rare worst result up to 0.2), showing similar trends in both years for crop classification accuracies. Figure 5.44 shows an overview graph summarizing the single date model differences between 1998 and 2001 while Figure 5.45 shows the differences for the progressive date model (for tables see Appendix F).

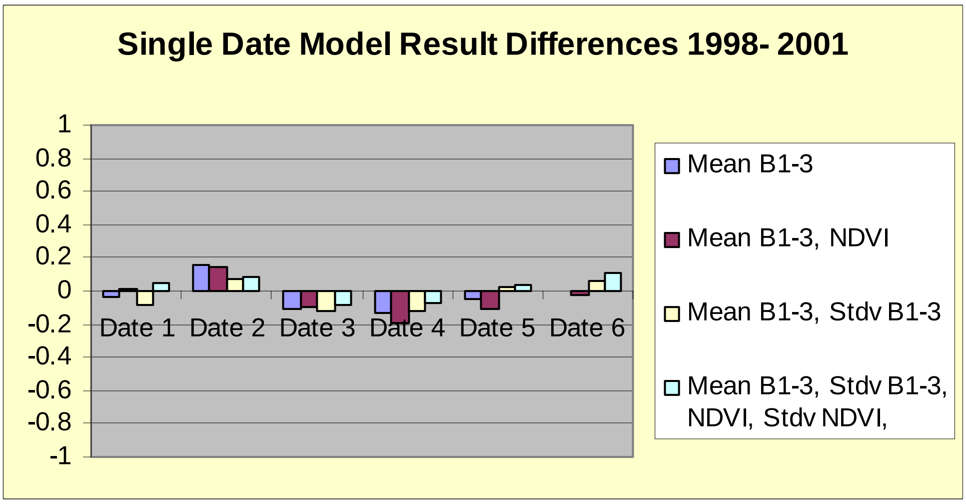


Figure 5.44: Model result differences for 1998 and 2001 single date crop discrimination models.

Date 1: 1998 DOY 181& 2001 DOY 210; Date 2: 1998 DOY 221& 2001 DOY 225; Date 3: 1998 DOY 240& 2001 DOY 242; Date 4: 1998 DOY 251& 2001 DOY 255; Date 5: 1998 DOY 287& 2001 DOY 282; Date 6: 1998 DOY 320 & 2001 DOY 319;

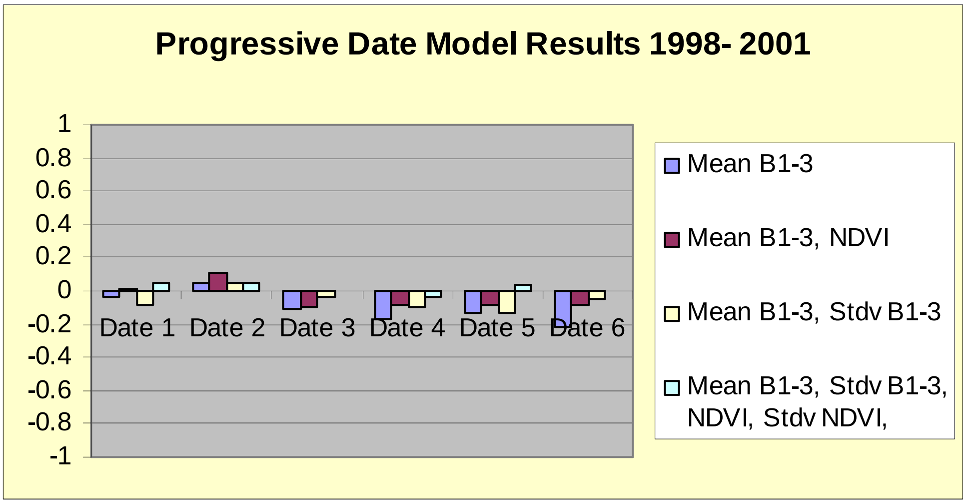


Figure 5.45: Model result differences for 1998 and 2001 progressive date crop discrimination models

Date 1: 1998 DOY 181& 2001 DOY 210; Date 2: 1998 DOY 221& 2001 DOY 225; Date 3: 1998 DOY 240& 2001 DOY 242; Date 4: 1998 DOY 251& 2001 DOY 255; Date 5: 1998 DOY 287& 2001 DOY 282; Date 6: 1998 DOY 320 & 2001 DOY 319;

5.4 Discussion

From the multitemporal SPOT 1998 and 2001 satellite imagery spectral measurements for band 1 (green), band 2 (red) and band 3 (near infrared) were retrieved for crop type barley, canola, chickpeas, lentils and wheat. It was observed in the typical spectral properties for each crop type that as the amount of green biomass on the ground increased, so did the absorption in band 2 (red wavelength) and the reflectance in band 3 (near infrared wavelength). During senescence the crops had reduced amounts of green biomass and hence the reflectance in band 3 decreased coupled with an increase in band 2. These observations agreed with reports in the literature (Badhwar and Henderson, 1981; Tucker and Sellers, 1986; Russ, 1993; Russ et al. 1993; for more details refer to Chapter 2). Chickpeas and lentils were found to be distinctively different to barley, wheat and canola. Together with their respective NDVI values all crop types could be visually distinguished.

Multiple factors influenced the crop development during a season. 1998 was a la Niña year (Wright, 2001); la Niña years are associated with higher spring rainfall and cooler daytime temperatures in the south east Australian region (Jones and Trewin, 2000) and hence an earlier season "break" (Liu et al, 2004). Sufficient rain fall was a prerogative for successful crop emergence (Hammer, 1983 considered a rainfall of 20 mm in winter over 1 or 2 days to be the criterion for planting on cracking clay soil). The 1998 crop season started distinctly earlier than in 2001. When analysing the sowing dates of canola (supplied by the farmers) it was observed that the average sowing date in 1998 was early May, while in 2001 canola was not sown until end of June. This obviously had a significant impact on the satellite signals obtained in i.e. July, when in 1998 some crops had emerged while there was no vegetation signal in 2001 yet. Vegetation signatures were compared in Figure 5.46; the NDVI of canola fields was plotted in both years 1998 and 2001, respectively.

It was observed that the seasonal development was not linear; the speed of crop development was influenced by climatic events (such as temperature and rainfall) during the season.

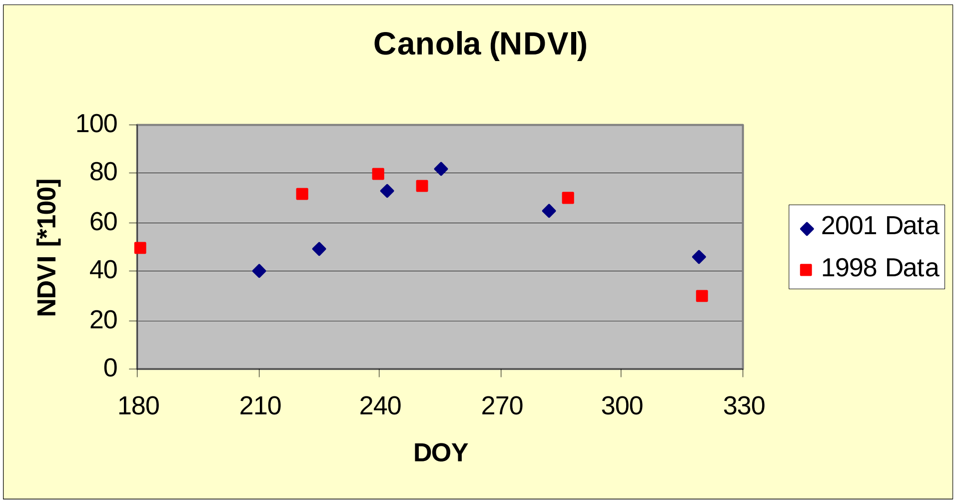


Figure 5.46: Temporal shift in the NDVI development of canola in 1998 and 2001 (see text for full explanation)

Seasonal effects are a significant challenge when transferring crop discrimination models without prior knowledge from one year to another. It is therefore necessary to build a database that includes many crop seasons to determine a “typical” crop season in south east Australia as a base line to adjust seasons to each other. Aigner (1999), and Aigner et al. (1999) reported building such a crop database with NOAA-AVHRR data (1995-1998) for the Gooroc test site when relating the satellite data to grain crop yields. In his study Aigner observed that the temporal behaviour of the NDVI varied with respect to season onset date and plateau duration. Li and Kafatos (2000) found the biosphere vegetation patterns in AHHRR data in the USA to be related to the El Niño/ La Niña effect. Reed et al (1994) related vegetation phenology to quantified AVHRR NDVI curve properties in the USA and Hill and Donald (2003) used such NDVI metrics in Western Australia to derive information about seasonal agricultural productivity. A regional multi-seasonal database utilizing NDVI metrics of remote sensing data with high temporal resolution (AVHRR or MODIS) together with climatic records needs to be built in future research to use seasonal information for the crop monitoring system in south east Australia.

Classification accuracies were obtained for each acquisition date with a discriminant function analysis. Using datasets from multiple dates, the classification accuracies could be improved significantly; in several models all fields were classified correctly. The data were compared to a similar dataset from 2001 and equivalent spectral properties and classification results were found. However, the models are currently limited to the five investigated crop types. Applying the derived discriminant functions to fields with other crop use will result in misclassifications. Hence further research is required to derive spectral properties of other crop types and to include those into the discriminant functions.

Wilkinson (2005) analysed over 500 classification results reported in the literature from 138 separate papers over a time frame of 15 years (1989-2003). He found that the mean classification accuracy (overall per cent correct) was 76.19% with a standard deviation of 15.59%, and that reported classification results did not improve over the 15 year time frame. He noted that the number of features used in classification experiments (mean 7.85) was relatively low, given the potential value of multitemporal and multi-sensor mapping approaches and the apparent sophistication of classification approaches. The work presented in this thesis took advantage of a multitemporal dataset in the progressive date models and achieved results (up to 100%) which were superior to the average results found by Wilkinson (2005).

Information on crop type and status, together with area statements can also give valuable information to other service providers of the farming community, such as logistical planning in receiving docks, insurance companies, etc.

5.5 Conclusions

Typical crop signatures were derived from SPOT satellite data for barley, canola, chickpeas, lentils and wheat. The NDVI gave a good understanding of crop status during the season. Two years, 1998 and 2001 were observed. The crop spectral reflectance values showed similar behaviour in both years, however the temporal pattern was not consistent when comparing both years. The temporal crop development was compressed and stretched, subject to climatic conditions. Thus seasonal shifts complicate classification model transfer from one year to the next. When using the discriminant models derived in this study, climatic information and approximate sowing dates need to be integrated to address the seasonal shift aspects.

The accuracies of crop discrimination models were greatly enhanced by multitemporal satellite data as there was much information about crops in the temporal domain. Classification accuracies greater than 80% were obtained as early as the end of August for both investigated years (1998 and 2001). Knowledge of the crop spectral properties derived from this study coupled with in situ data of only a few selected "typical" crop fields should result in very good classification accuracies for the five investigated crop types in the future. It is anticipated that crop signatures in other south east Australian regions under similar cropping systems and soil types are comparable to the ones observed in the Gooroc area. However this will need to be confirmed.

The derived spectral properties of crops grown in south east Australian conditions comprise a valuable baseline data set for typical crop fields, allowing discrimination of atypical field; this information can be used to address atypical fields with precision farming management.

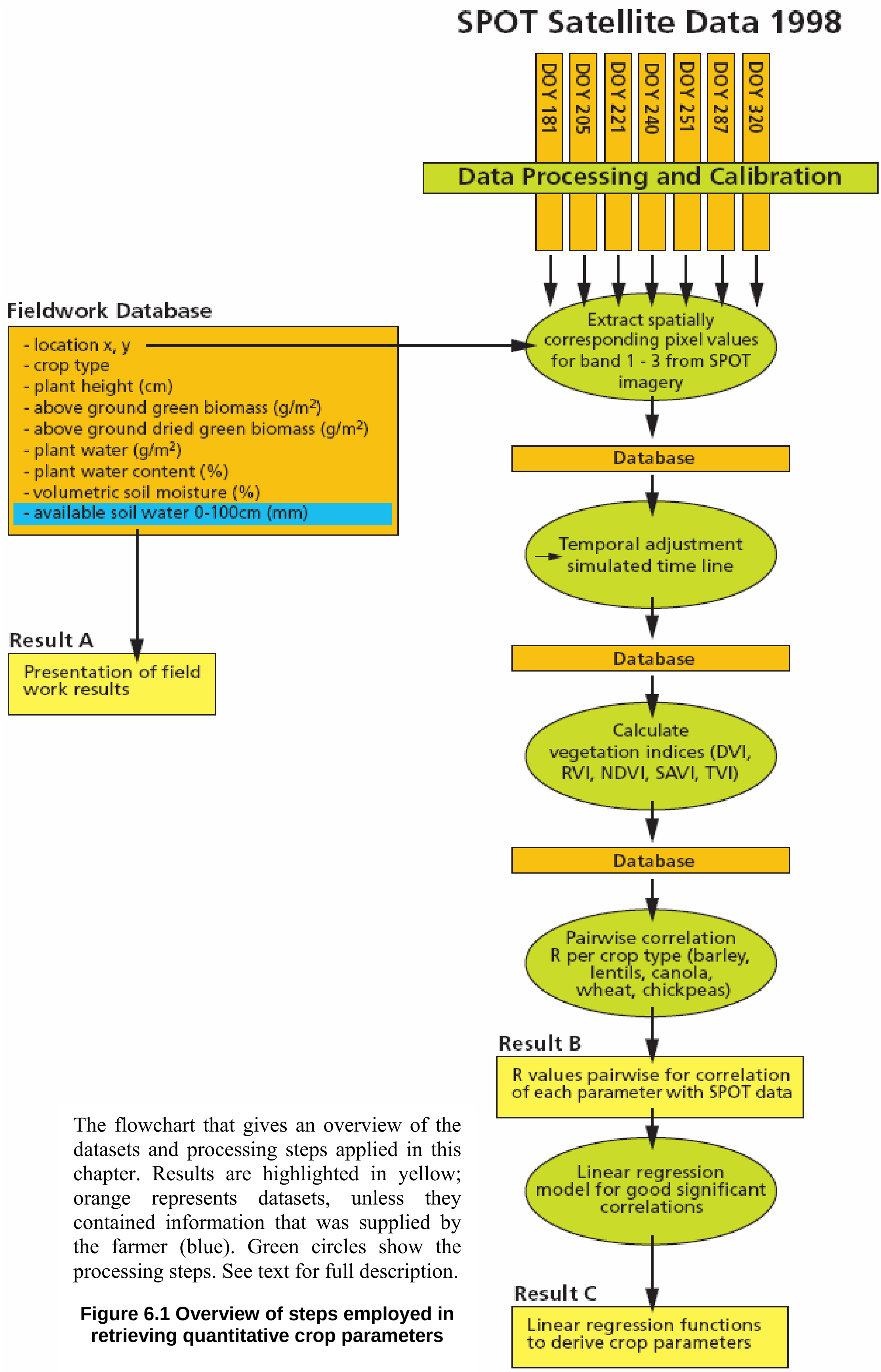
6. Parameter estimation for crop monitoring

6.1 Introduction

Quantitative crop parameter maps are most useful for precision farming applications. Farmers gain knowledge of biophysical crop parameters in different zones in the field, which enable them to apply the appropriate amounts of fertilizers and chemicals to areas in the paddock where they are required. In addition, land managers are alerted to areas that perform outside the expected crop development, can monitor the quantitative response to management decisions (for example urea application) and can schedule harvest operations (subject for example to remaining water content in the crop). Information on the repetitive pattern of quantitative crop parameters over multiple years enables the farmer to delineate management zones within the paddock. Therefore the aim of this chapter is to investigate how crop plant parameters in south east Australia are related to the SPOT remote sensing data. The crop parameters tested were plant height, above ground green biomass, dried above ground green biomass, spatial plant water content and percentile plant water content. Furthermore studies were also conducted to see if there were correlations between the SPOT satellite data and two soil moisture parameters, namely volumetric soil moisture content in the top 5 centimetres and available soil water in the first metre below surface. An understanding of the statistical relationship between crop parameters and satellite remote sensing data enables the production of detailed spatial paddock maps with quantitative crop parameters. The plant parameter estimates between multiple satellite acquisition dates also enable the production of quantified change maps.

6.2 Methods

The data used in this chapter are the processed and calibrated SPOT satellite data from 1998. Furthermore data that were collected during extensive field work in 1998 and the farmer's neutron probe measurement were utilized (see Chapter 4). The results of measured field data were presented. Pixel values of the satellite data were extracted from the location that the field measurements were made. The precise date when field work was conducted was simulated in the remote sensing data by means of linear temporal adjustment between satellite acquisition dates. From the remote sensing data various vegetation indices were calculated. These, together with the values from SPOT band 1-3 were pairwise correlated with the field data. The results of the Pearson Product Moment coefficients were presented and for good results linear regression functions for crop parameter estimation were derived. Figure 6.1 outlines the steps employed in undertaking the parameter estimations and analysis presented in Chapter 6.



The flowchart that gives an overview of the datasets and processing steps applied in this chapter. Results are highlighted in yellow; orange represents datasets, unless they contained information that was supplied by the farmer (blue). Green circles show the processing steps. See text for full description.

Figure 6.1 Overview of steps employed in retrieving quantitative crop parameters

6.2.1 Data extraction

A “FIELDWORK” GIS point data layer was created. Each sample point (x, y) of the Super-test sites was attributed with the data collected during the field visits:

- Plant height
- Above ground green biomass [g/m^2]
- Above ground dried green biomass [g/m^2]
- Plant water [g/m^2]
- Plant water content [%]
- Volumetric soil water content [%]
- Available Soil water 0- 100 cm depth [mm]

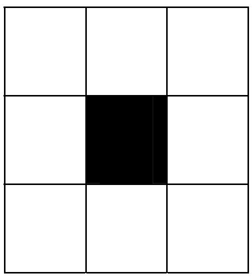


Figure 6.2: Field sample grid (3x3 pixels)

The field samples had been collected in a 60m x 60 m grid which corresponded to a 3 x 3 pixel size from the SPOT satellite. Reason therefore was to ensure that after multiple field trips with destructive biomass sampling the signal received from the sampling pixel was still representative. As the field was homogenous over the 60m x 60m area, the samples were representative of the centre pixel at that time. The satellite data were extracted for the location of the centre pixel (Figure 6.2).

Figure 6.3 shows an overview of the sampling locations. The 60m x 60m grid started 80 metres into the field, past the headlands (in which a different sowing direction was present than further into the field).

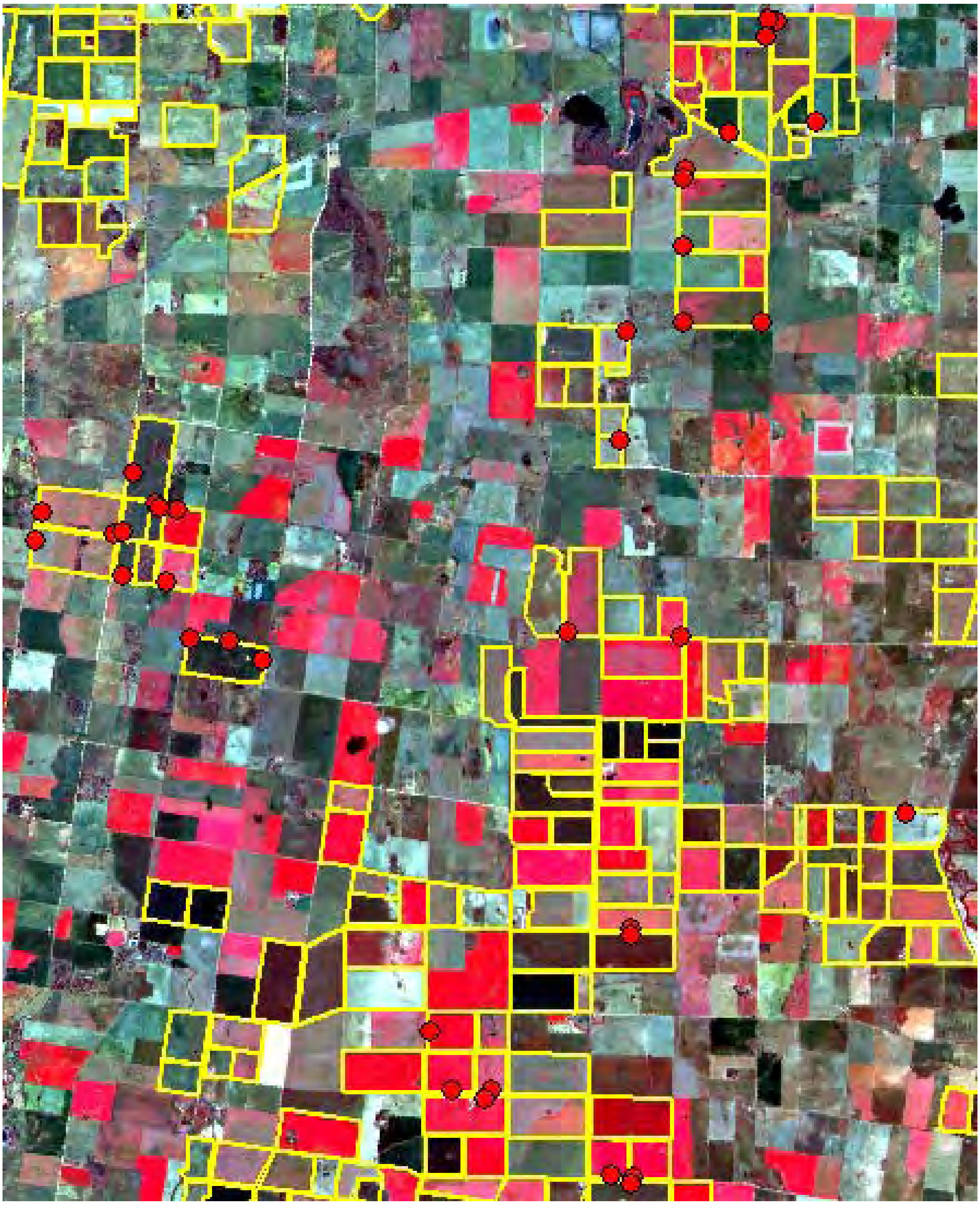


Figure 6.3 Location of sampling points of field work

6.2.2 Simulated timeline from SPOT data

	SIM	REAL
30-Jun	13.25	13.25
1-Jul	13.43	
2-Jul	13.61	
3-Jul	13.80	
4-Jul	13.99	
5-Jul	14.18	
6-Jul	14.36	
7-Jul	14.55	
8-Jul	14.74	
9-Jul	14.93	
10-Jul	15.11	
11-Jul	15.30	
12-Jul	15.49	
13-Jul	15.68	
14-Jul	15.86	
15-Jul	16.05	
16-Jul	16.24	
17-Jul	16.43	
18-Jul	16.61	
19-Jul	16.80	
20-Jul	16.99	
21-Jul	17.18	
22-Jul	17.36	
23-Jul	17.55	
24-Jul	17.74	17.75
25-Jul	17.93	
26-Jul	18.08	
27-Jul	18.24	
28-Jul	18.39	
29-Jul	18.55	
30-Jul	18.71	
31-Jul	18.86	
1-Aug	19.02	
2-Aug	19.18	
3-Aug	19.33	
4-Aug	19.49	
5-Aug	19.64	
6-Aug	19.80	
7-Aug	19.96	
8-Aug	20.11	
9-Aug	20.25	20.25

Table 6.1: Comparison of simulated and actual pixel value

The field work was conducted on the days of the ERS satellite overpass. These dates did not correspond to the SPOT acquisition dates. Therefore adjustments were applied to the SPOT data.

The values of the centre pixel were extracted for the green, red and near infrared band (band 1-3), for each satellite acquisition date. A linear regression was applied to determine the simulated values of the days between the acquisition dates. An example (SPOT Band 3) was given in Table 6.1 for the McKew paddock (Chickpeas) for the time range from 30 June 1998 (DOY 181) until 09 August 1998 (DOY 221). In the column "SIM" all simulated values were given between the acquisition dates (which were marked in yellow). The simulated value for the 24 July 1998 was 17.74 % reflectance. When the simulated value was compared to the real SPOT data acquired on 24/07/1998, the extracted pixel value corresponded very well with 17.75%.

The first field trip took place on the 17/6/98, but the first SPOT data acquisition was not acquired until 30/6/98. Hence simulation of the SPOT data values for the 17/6/98 could not be achieved. The same problem occurred at the end of the season when the last field trip took place on the 9/12/98, but the last SPOT data acquisition was on the 16/11/98. Hence also on the 9/12/98 no SPOT data are available to match with the field work. It is regrettably not to be able to utilize the field work conducted on those dates for the optical remote sensing study; but since early in the season often only bare grounds were seen and at the end of season multiple fields were already harvested, only the least important dates were lost for correlation analysis. The field work data were nevertheless presented to give the reader a good understanding of the crop development in south east Australia throughout the season.

However, for the time frame that major crop activity occurred, field work and simulated SPOT data were available for analysis on four equally spaced dates, namely DOY 203 (22/7/98), DOY 238 (26/8/98), DOY 273 (30/9/98) and DOY 308 (4/11/98).

6.2.3 Vegetation Indices

Next to band 1 to 3, also several vegetation indices were calculated to investigate their response to the crop parameters under south east Australian conditions. The vegetation indices that were included in this study were mainly classical vegetation indices that had shown good results in other parts of the world. The vegetation indices had been discussed in detail in Chapter 2. Furthermore a vegetation index that was based on three rather than two bands was tested in this study. It was based on a conceptual idea for hyperspectral data from Broge and Leblanc (2001) and was modified for operational broadband SPOT data. Thus, the vegetation indices included in this study were as follows:

Normalized Difference Vegetation Index

NDVI = (NIR-R)/(NIR+R) (Rouse et al, 1973)

Difference Vegetation Index

DVI = (NIR-R) (Tucker, 1979)

Ratio Vegetation Index

RVI = (NIR/R) (Jordan, 1969)

Soil Adjusted Vegetation Index

SAVI = (1+ L) [(NIR- R)/ (NIR + R + L)] L= 0.5 (Huete, 1988)

The value 0.5 for L was widely recognized in the literature to be acceptable for field crops, in particular since the crops under investigation were not tall or high density crops (such as maize for example). In south east Australia typically less biomass per hectare is found in dryland cropping conditions compared to North America or Europe.

Triangular Vegetation Index

The author modified an index that Broge and Leblanc (2001) suggested. The modifications adopted the index for the wavelength of the SPOT satellite. The idea was to calculate the area span up between the triangle created by the reflectance of the green (G), red (R) and near infrared (I) (Figure 6.4).

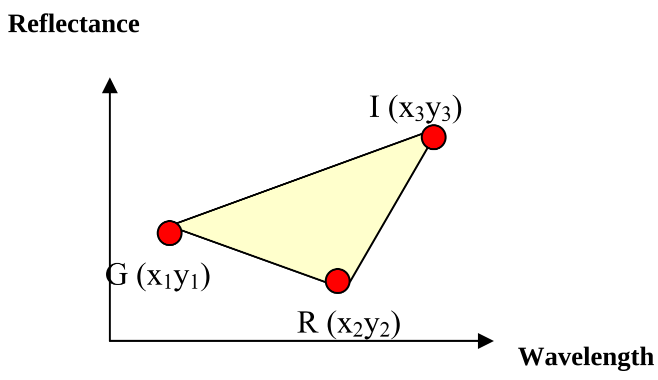
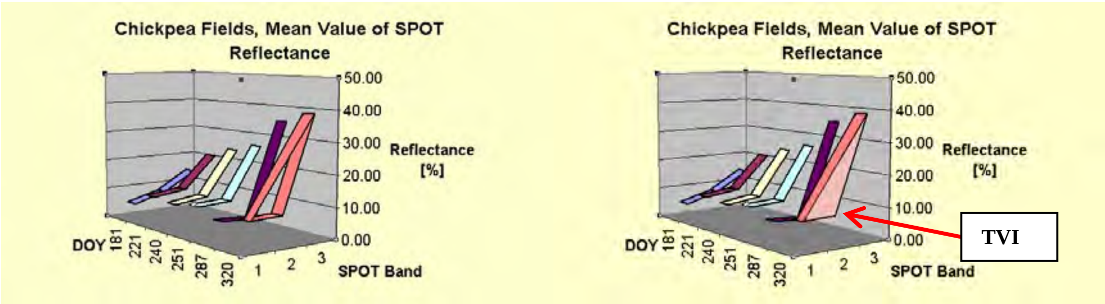


Figure 6.4 Principle of modified Triangular Vegetation Index TVI

$$\text{Area}(\Delta\,\text{GRI}) = \tfrac{1}{2}\,\left|\,[x_1 (y_3 - y_2) + x_2 (y_1 - y_3) + x_3 (y_2 - y_1)]\,\right|$$

For the SPOT satellite the centre of the green band (Band 1) was at 545nm, 645nm for the red band (Band 2) and 835nm for the near infrared band (Band 3); hence the calculation for the TVI triangle was:

$$\text{TVI} = \text{Area}(\Delta\,\text{GRI}) = 0.5\,\left|\,[545 (y_3 - y_2) + 645 (y_1 - y_3) + 835 (y_2 - y_1)]\,\right|$$



An example of the TVI triangle for chickpeas fields on DOY 320. Looking at the timeline, the triangle size was related to the amount of green vegetation; on the fields under investigation the absorption in the red (low reflectance values) increased, as did the reflectance in the near infrared (high reflectance values), related to greenness of vegetation. Lush green fields had a greater triangle area than sparse green vegetation.

Figure 6.5 Visual application of TVI to chickpea data

6.2.4 Statistical analysis

Band 1-3, together with the vegetation indices and plant parameters were exported to the statistical software package JMP. The means and standard deviations of the field measurements were plotted as a function of time and discussed. The graphs were presented in the results section demonstrating the crop development.

From the remotes sensing data and the crop parameters, the Pearson Product Moment coefficient R was calculated for pairwise correlations. Pairwise correlations were conducted between each of the plant parameters (left column) and each the remote sensing data (right column), as outlined in Figure 6.6.

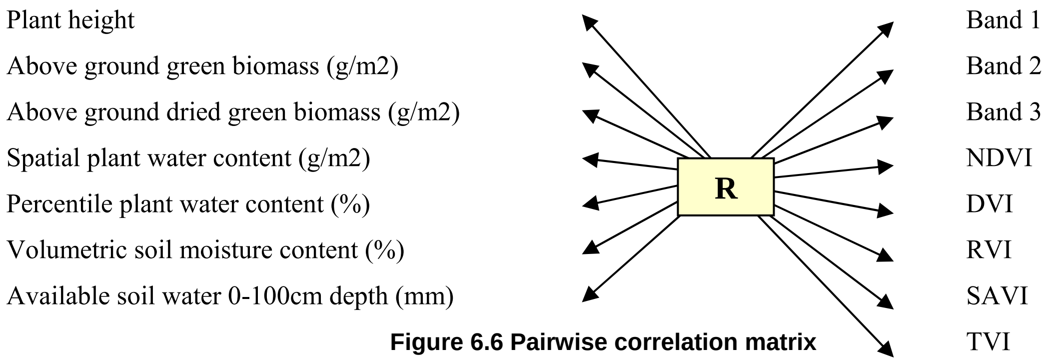


Figure 6.6 Pairwise correlation matrix

6.3 Results

6.3.1 Plant height

During the field trips the height growth of the crops was measured from seedlings to full maturity. The growth patterns are crop type specific. The data can be found in Appendix G.

Plant height field measurements

Only a small number of barley fields were available on the two cooperating farms. In 1998, Farmer 14 only sowed one barley field which in August was severely affected by an armyworm infestation; it was consequently sprayed out and no harvest was obtained (see Chapter 8.3.2 for more details on the armyworm invested Merrillees field). Farmer 15 had two barley fields, but one had to be omitted during the last two field trips as there was not enough time to sample all fields. The maximum barley height reached was approximately 70 cm on DOY 308 (4/11/1998). Canola was the tallest crop sampled of the five investigated crop types, reaching a maximum mean value of 110 cm on DOY 273 (30/9/1998). A major growth spurt occurred in September, when the crop added 60 cm in 35 days. As the canola pods filled and became heavier, the plant height diminished due to the pull of gravity. Chickpeas reached their maximum height of 42 cm (mean) on DOY 343 (9/12/1998). Before then the plant growth was steady throughout the season. Lentils were the shortest crop of the five investigated crop types, with a maximum height reached in November (mean was 32 cm). Similar to canola, at the end of the season the plant height was reduced due to the weight of the filled pods. Wheat reached a maximum height of 75 cm (mean) in November, before slightly “nodding” its heads at maturity. Figure 6.7 shows the measured plant height throughout the vegetation period.

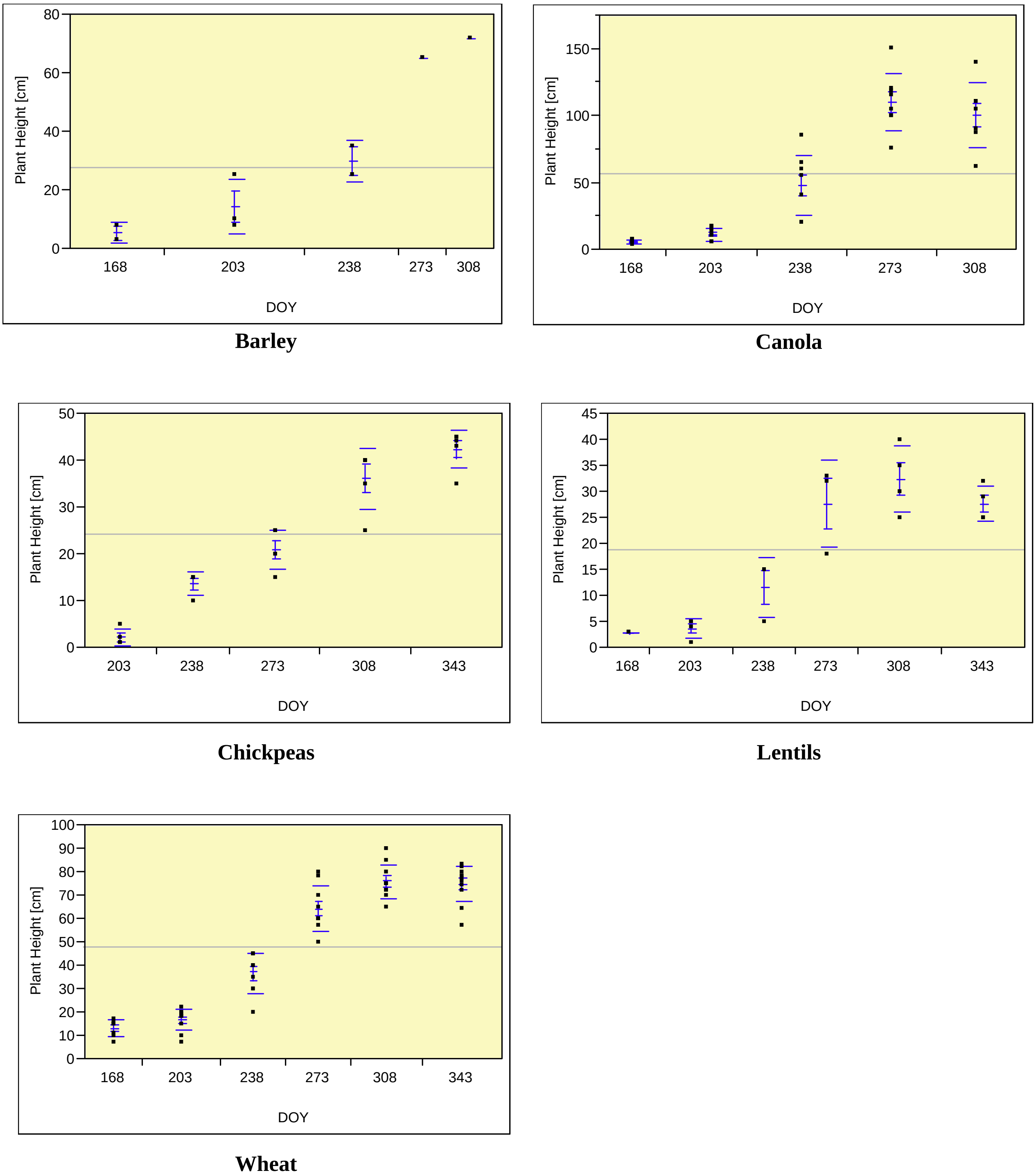


Figure 6.7 Analysis of plant height [cm] over time [DOY] in 1998 (see text for full explanation)

Plant height correlations

The Pearson Product-Moment coefficient R was calculated for pairwise correlations with the remote sensing parameters and the results were summarized in Figure 6.8. The correlation table can be found in Appendix H.

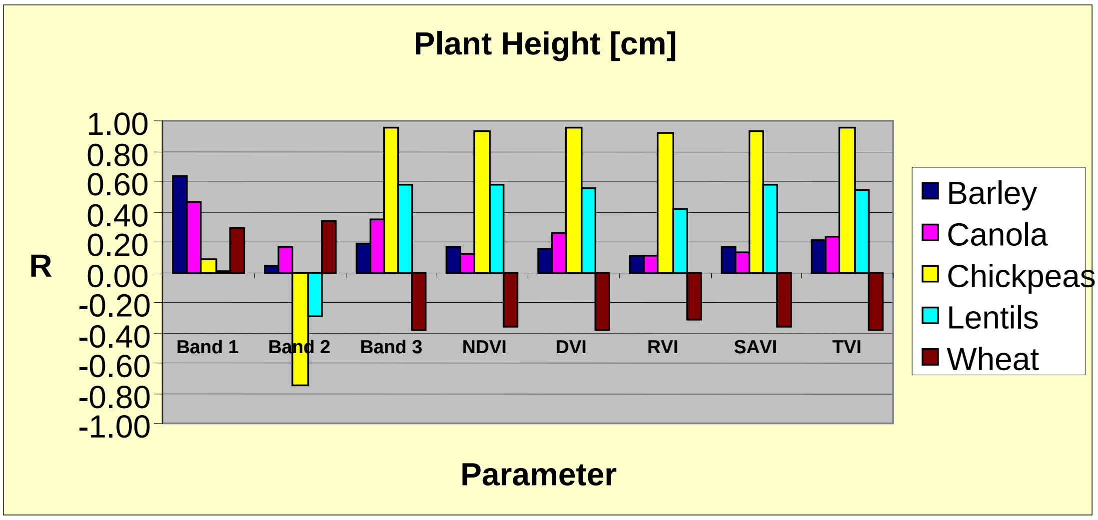


Figure 6.8 Correlation results for plant height and remote sensing parameters

Interestingly, wheat had a poor negative R for Band 3 and all the vegetation indices. From Figure 6.9 it can be observed that as wheat grew, the reflectance in the near infrared band increased (and hence the vegetation index DVI), but towards maturity wheat turned yellow and dried up, and the near infrared reflectance decreased. Thus the relationship was not linear. Therefore either a non-linear model needs to be fitted or the linear fit needs to be divided into two linear regression models, before and after vegetation index maximum; however more acquisition dates were needed for this task to have meaningful regressions. There was no significant relationship between plant height and remote sensing parameters to report for barley and canola. More data points were needed for barley (n=7). Lentils showed some relationship between Band 3 and the vegetation indices, but the nonlinear growth and onset of senescence (yellowing) also complicated the linear relationship.

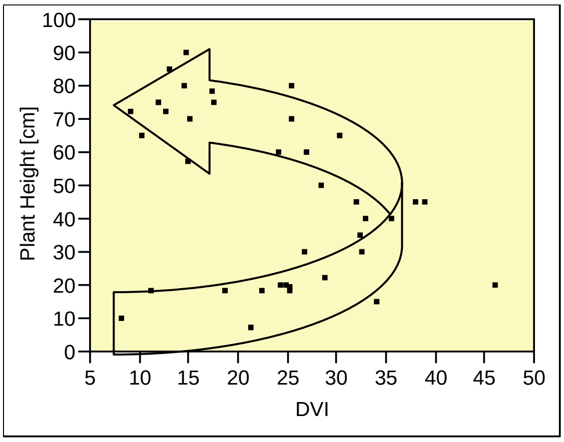
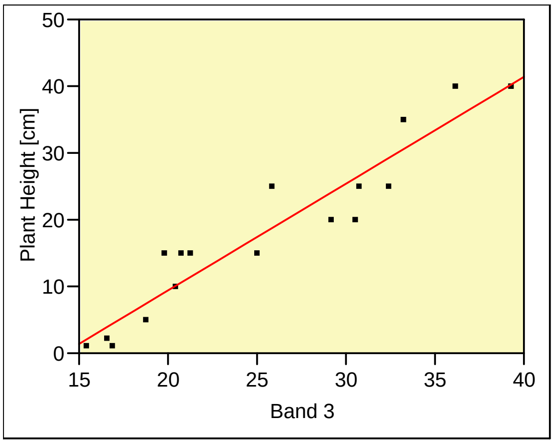


Figure 6.9: Path of DVI values as wheat grew in 1998

The best result was achieved by chickpeas and Band 3, with a Pearson Product-Moment coefficient R = 0.96 and a significance probability of 0.0000000006 (n=18). In fact, all the Vegetation Indices were significantly correlated to the plant height of chickpeas. A linear regression equation with R^2 = 0.91 (Band 3) was fitted for plant height of chickpeas (Figure 6.10):

Chickpeas

Plant Height [cm] = -22.55153 + 1.5986302* Band 3



R^2= 0.91

Figure 6.10: Linear regression for chickpea plant height and SPOT band 3

6.3.2 Above ground green biomass

Above ground green biomass is also referred to in the literature as “green biomass”, “phytomass” and “wet plant weight”. Several factors were causing the differences in the $1m^2$ biomass measurements of similar crop types on the same sampling date:

- Plant height
- Number of plants per m^2
- Crop development (different tissue density) and
- Plant “bulkiness”

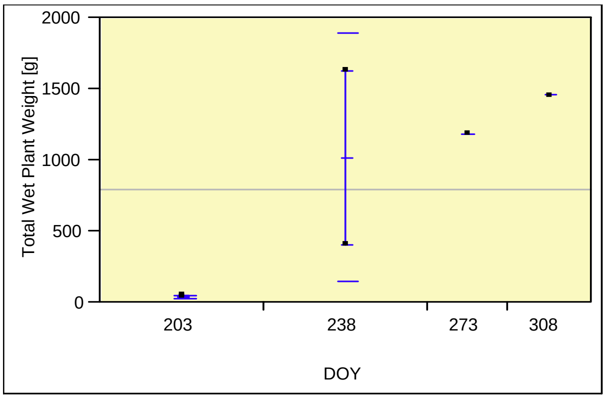
As an example the photograph of two canola fields were given in Figure 6.11. At the end of August 1998, the Weir paddock had a very little green biomass (272 g/m^2; height 20 cm, sowing date: 19/5/1998). At the same time Adeline South had the large amount of biomass of 3762 g/m^2 (height 55 cm, sowing date: 5/5/1998).

Weir paddock (left): 272 g/m^2; Adeline South paddock (right): 3762 g/m^2

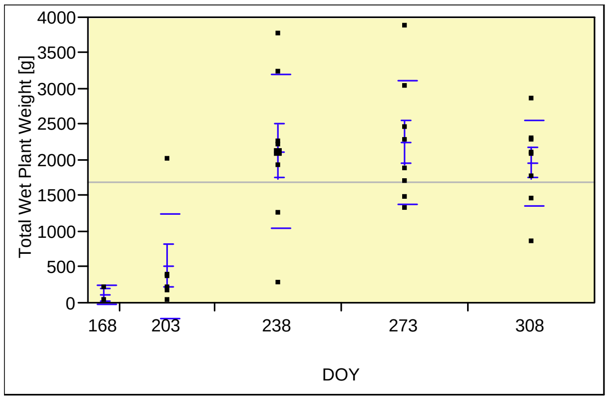
Figure 6.11: Canola fields with various amounts of biomass

Green biomass field measurements

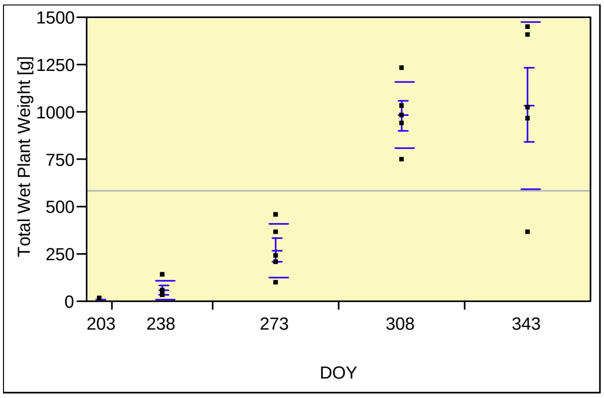
Multiple canola fields were available. A great increase in biomass occurred between DOY 203 and 238. At the end of the season the biomass values decreased due to the drying out of the crop associated with maturing. A similar pattern was observed in wheat, however the strong increase continued until DOY 273. Chickpeas and lentils produced the majority of their biomass later than wheat, barley and canola, between DOY 238 and 308. Lentil fields were particularly prone to "patchiness" resulting in a wide range of biomass data. Figure 6.12 shows the amount of green biomass (g/m^2) in 1998.



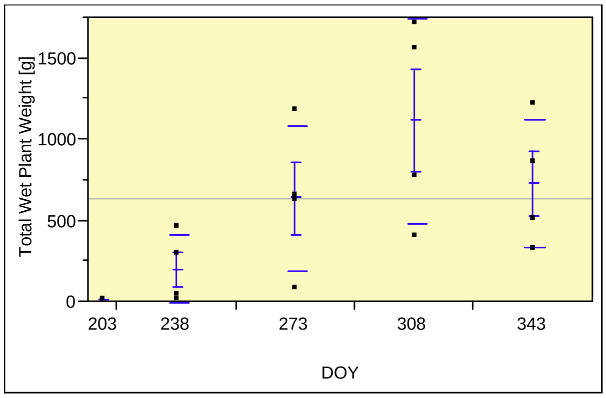
Barley



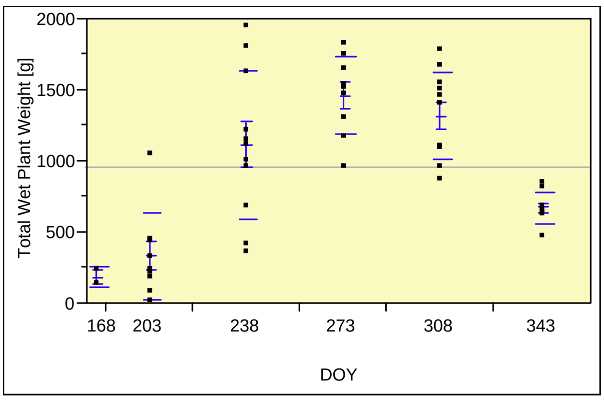
Canola



Chickpeas



Lentils



Wheat

Figure 6.12 Analysis of green biomass [g/m^2] over time [DOY]

Green biomass correlations

From the pairwise correlations of above ground green phytomass with remote sensing parameter the Pearson Product-Moment coefficient R was obtained and the results were documented in Figure 6.13.

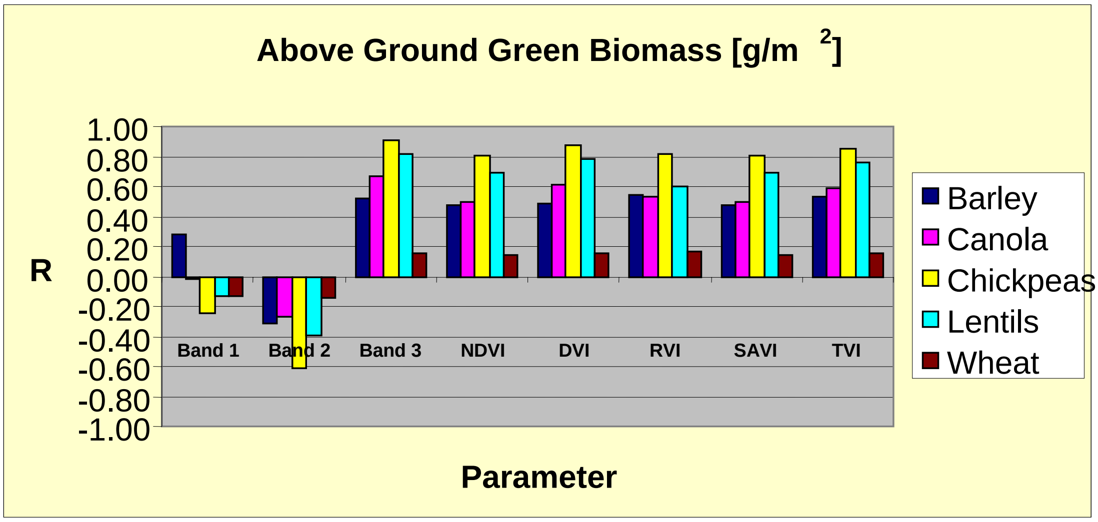
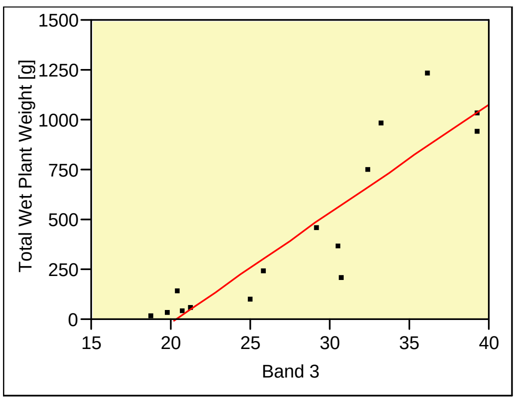


Figure 6.13 Correlation results for green biomass [g/m²] and remote sensing parameters

As with height, also for above ground green biomass best results are obtained for chickpeas (Figure 6.14, R= 0.91; n= 15; significance probability= 0.0000031328; R^2= 0.82).

Chickpeas

Green biomass [g/m²] = -1106.794 + 54.718622 *Band 3



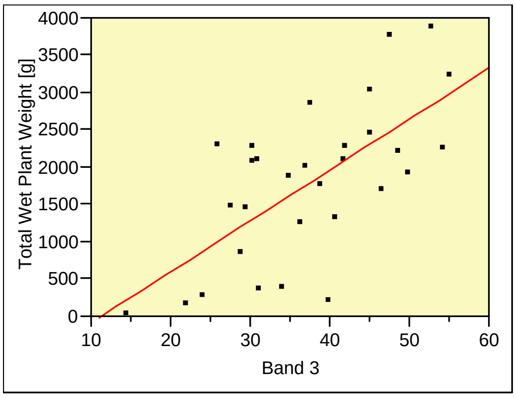
R^2 = 0.82

Figure 6.14: Linear regression for chickpea green biomass and SPOT band 3

The biomass readings of lentils and canola showed also a significant relationship with the remote sensing parameters, in particular with the near infrared band of SPOT (Band 3) (Figure 6.15). In the case of canola this relationship was weaker than for lentils. The vegetation indices showed similar trends as the red band. Here the DVI followed by the TVI was most sensitive. Band 2 (red band) had "mirrored" – in this case negative –correlations to band 3 and the vegetation indices. This was often observed in the study. The correlation results for band 1 and green biomass were non-significant R values.

Canola

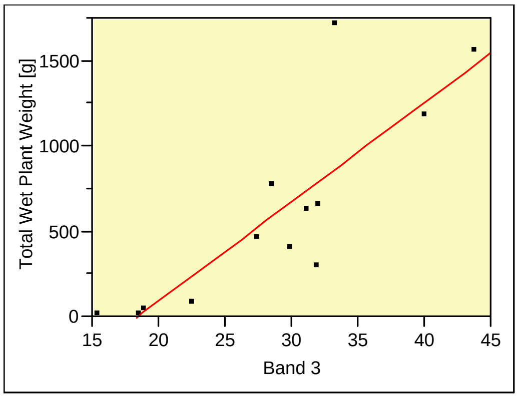
Green Biomass = -758.4618 + 68.262233* B 3



n=30; significance probability = 0.0000535006; R= 0.67; R^2= 0.45

Lentils

Green Biomass = -1070.533 + 58.168031 *B 3



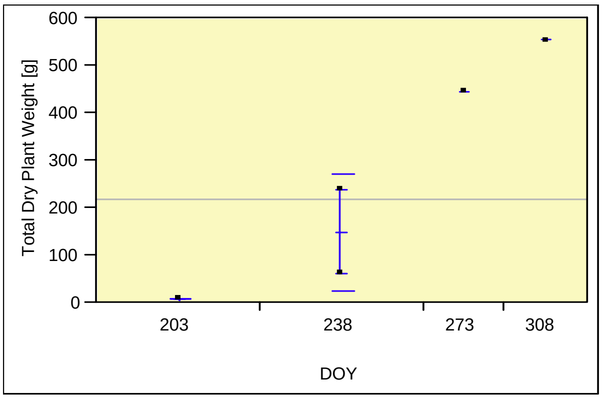
n=13; significance probability= 0.000679393;R= 0.82; R^2= 0.70

Figure 6.15 Linear regression function for canola and lentil green biomass estimation

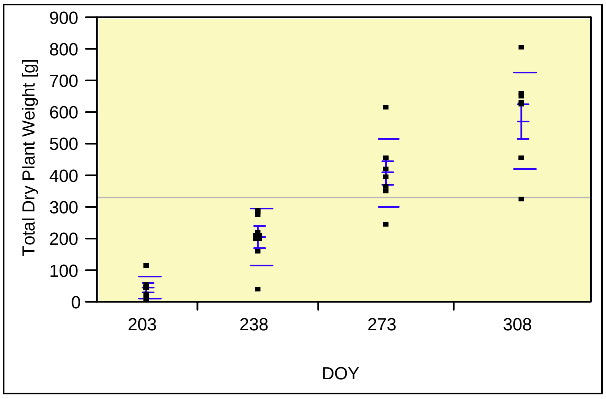
6.3.3 Above ground dried green biomass

Dried green biomass field measurements

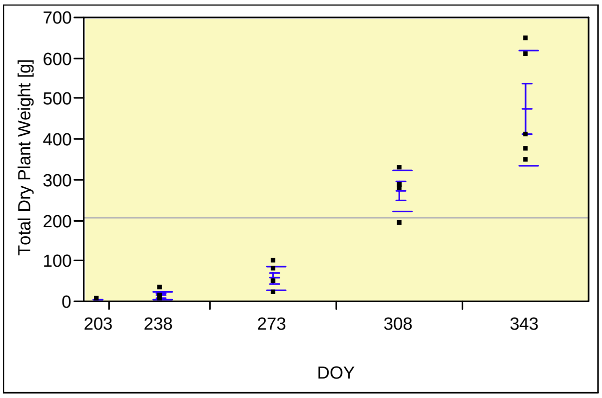
For all crop types the dried green biomass measurements increased steadily throughout the season. Toward the end of the season the plants contain less water and more substances, such as lignin, proteins, starches etc. However, the dried biomass of wheat slightly decreased at the end of season. In the field it was noticed that the soil became more visible, and the plants were mainly formed by the stems and ears filled with wheat grains. The decrease in biomass was explained that in wheat often only the flag leaves remained; the lower leaves shrivelled up and were dropped on the ground where they disappeared in the self-mulching cracks of the dry clay soils or were removed by fauna (Figure 6.16).



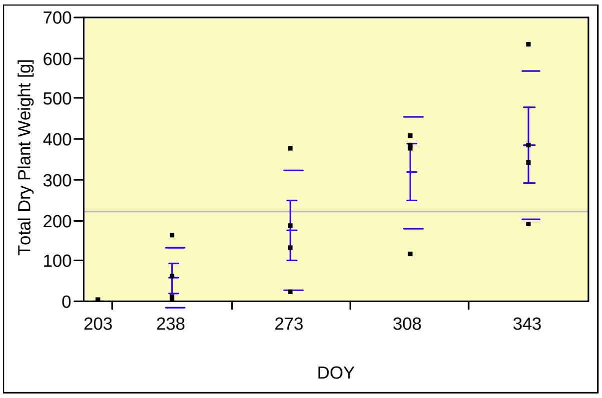
Barley



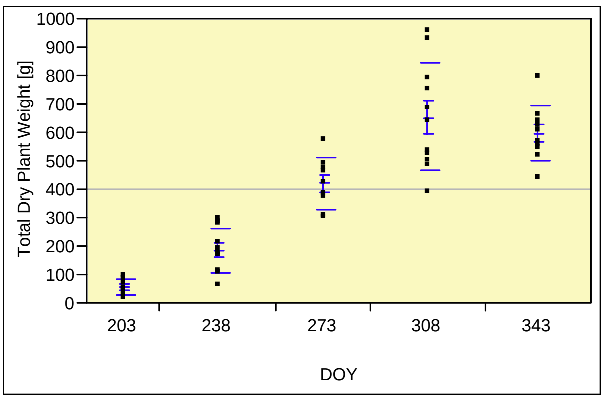
Canola



Chickpeas



Lentils



Wheat

Figure 6.16 Analysis of dried green biomass over time [DOY]

Dried green biomass correlation

Canola showed a significant relationship between band 1 and the dried biomass (Figure 6.17). In 1998, from June to November, the reflectance of band 1 for canola slightly increased (from about 5% to 10%) as did the dried biomass, hence the correlation. However, in the 2001 SPOT data, this increase was not observed for canola and therefore it was not expected to use band 1 to predict dried biomass. Wheat showed a negative relationship between band 3 and the vegetation indices. The best correlations results once again were obtained by chickpeas (R= 0.91 for band 3; see Figure 6.18) (lentils also showed some relations with an R= 0.64, probability significance = 0.018211147).

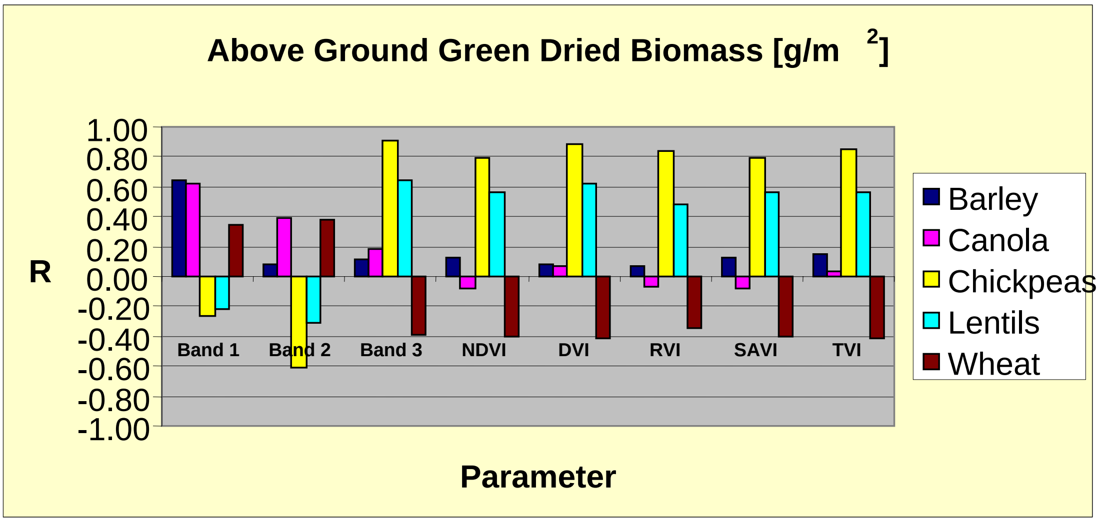
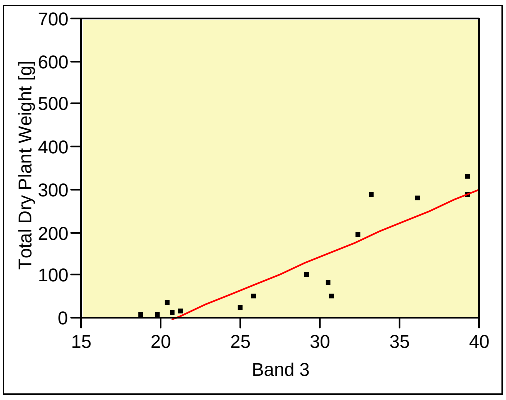


Figure 6.17 Correlation results for dried green biomass and remote sensing parameters

Chickpea

Above ground dried green biomass [g/m^2] = -326.2893 + 15.673842 *Band 3



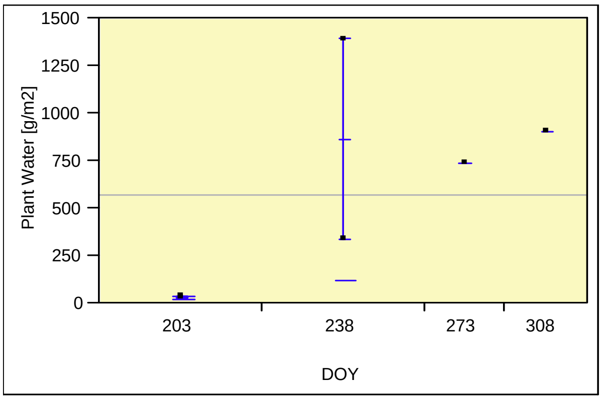
n=15; significance probability = 0.0000025753; R= 0.91; R^2= 0.83

Figure 6.18: Linear regression for chickpea green dried biomass and SPOT band 3

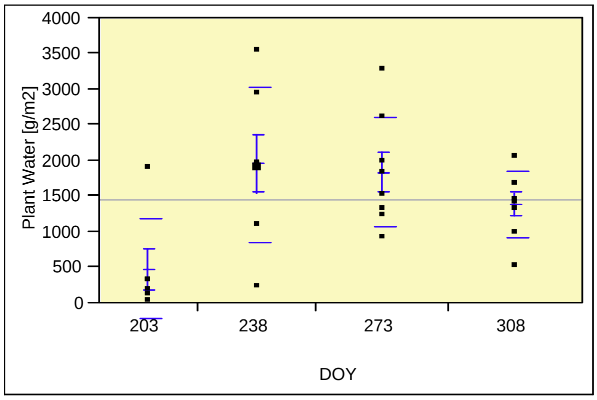
6.3.4 Spatial plant water content

Plant water content field measurements

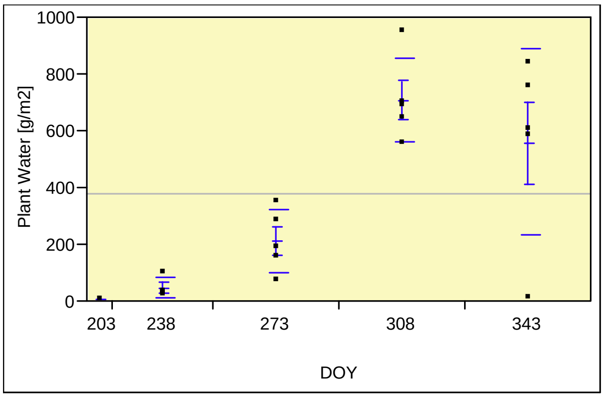
Plant water content measured the amount of water [g] on the area of 1 m^2. Early in the season there was little biomass on the field, and hence little plant water (Figure 6.19). As the season progressed the amount of plant water increased until the plants dried out while maturing, and consequently reducing the amount of plant water per area of the field. Therefore the measurements over time displayed a curvature.



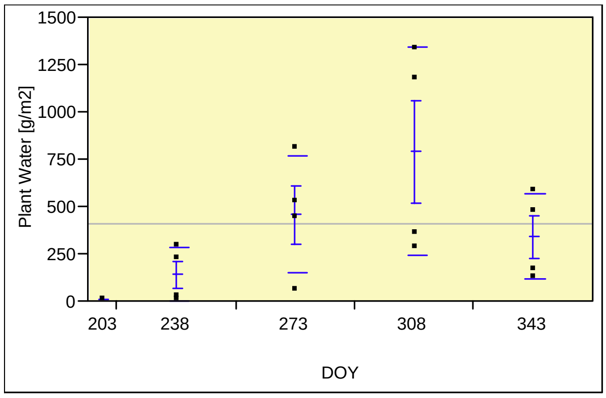
Barley



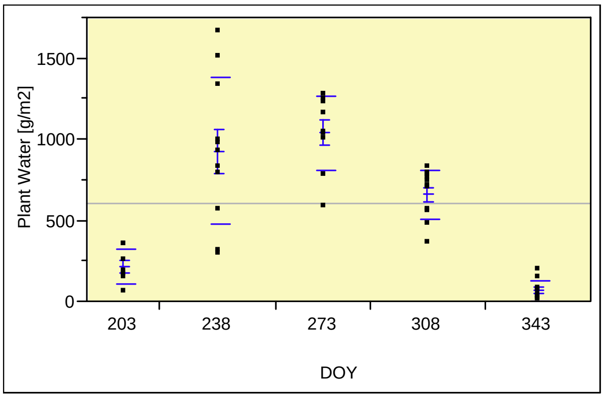
Canola



Chickpeas



Lentils



Wheat

Figure 6.19 Analysis of plant water [g/m^2] over time [DOY]

Plant water content correlation

The correlation coefficient R for plant water [m^2] and remote sensing parameters showed that all crops displayed a positive correlation for Band 3 and the vegetation indices (Figure 6.20).

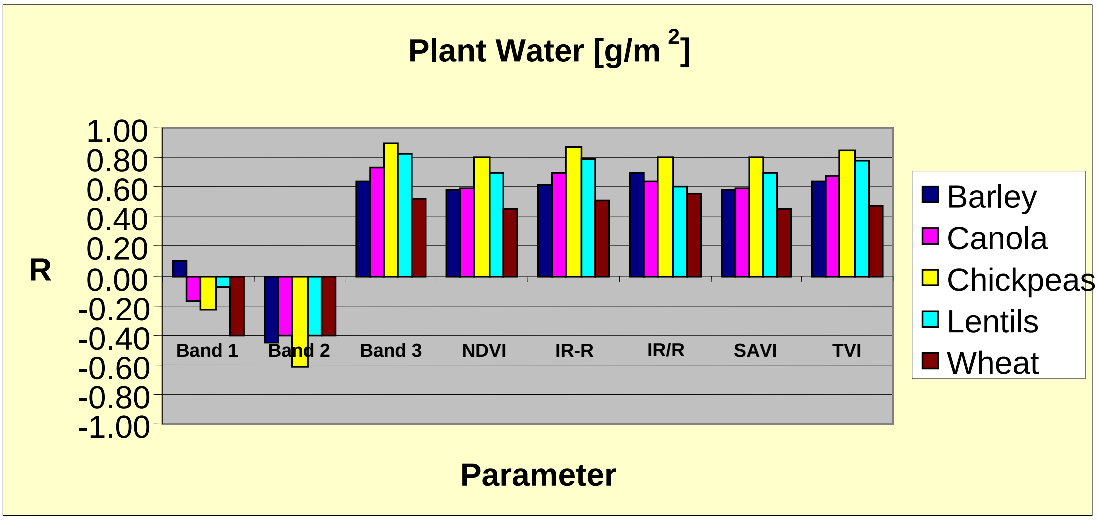
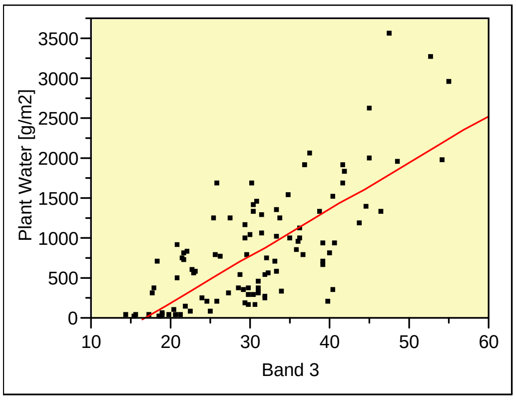


Figure 6.20 Correlation results for plant water [g/m^2] and remote sensing parameters

This indicated that a general model which included all crop types could be fitted. The results for the different indices were as follows: R^2 (NDVI) = 0.27; R^2 (DVI) = 0.47; R^2 (RVI) = 0.30; R^2 (SAVI) = 0.28; R^2 (TVI) = 0.43; R^2 (Band 3) = 0.52. The R^2 values were significant, but only moderately correlated. Once again Band 3 outperformed all the vegetation indices. The estimation of crop water [g/m^2] for chickpeas, canola and lentils could be improved by application of crop specific regressions (Figure 6.21).

All crops

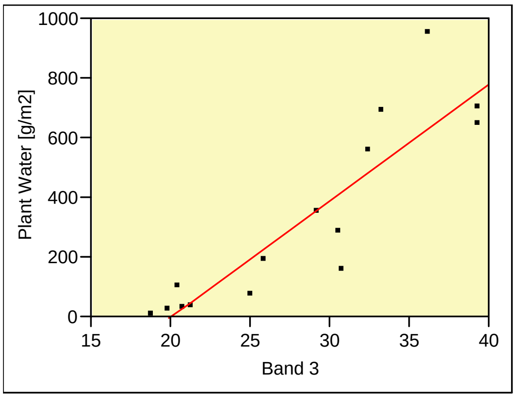
Plant Water = -974.3553 + 58.545353 *B 3



R^2= 0.52

Chickpeas

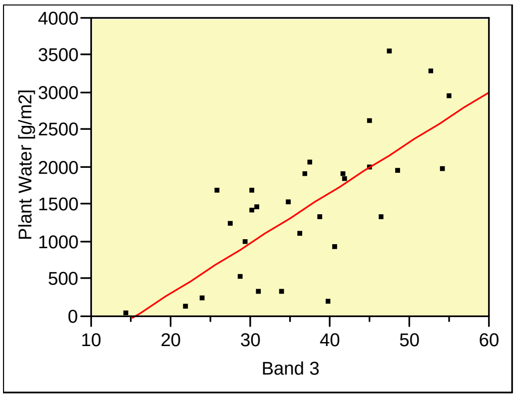
Plant Water = -780.5049 + 39.04478 *B 3



R^2= 0.80

Canola

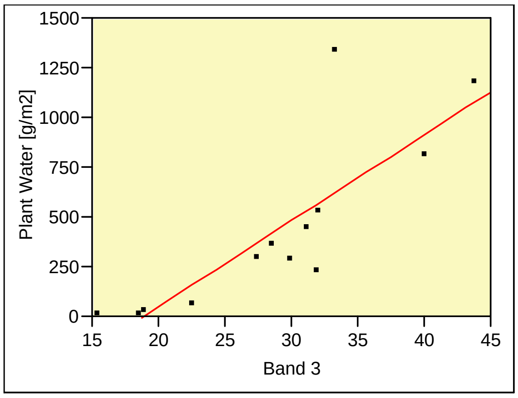
Plant Water = -1039.164 + 67.587022* B 3



R^2= 0.54

Lentils

Plant Water = -811.6715 + 43.199112 *B 3



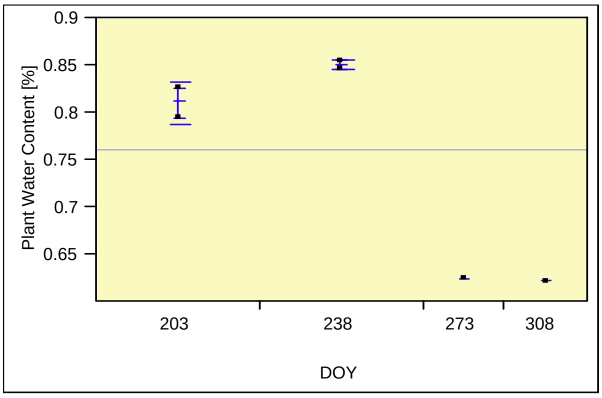
R^2= 0.68

Figure 6.21: Linear regressions for green dried biomass and SPOT band 3 for all crops, chickpeas, canola and lentils

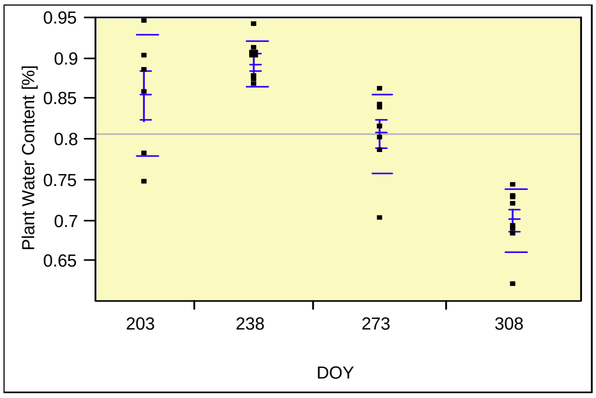
6.3.5 Percentile plant water content

Percentile plant water content field measurements

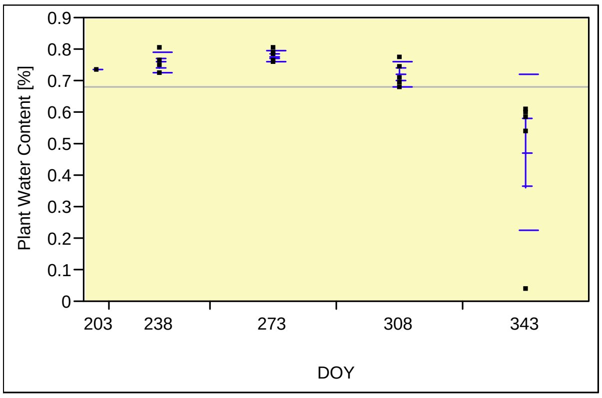
This plant measure determined the percentile amount of water in the plant compared to plant matter. Lush green vegetation had high percentile water content, while matured crop had very little water (Figure 6.22). In general it measured plant maturity, however diseased plants often dried up also and therefore had little water content. An example therefore was the chickpea sample of DOY 343 from an Ascochyta blight infested area in the field, which was totally dried up and had a water content of only 0.04%. The sample was taken from a special location (not the regular sampling point) in the Woolshed paddock. This sample was not included in the correlations; there was no SPOT data available for the December field data.



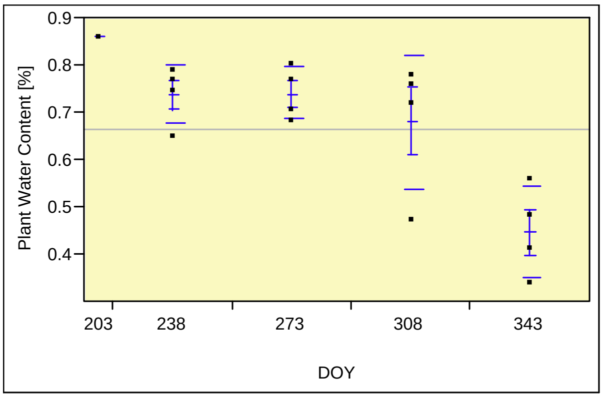
Barley



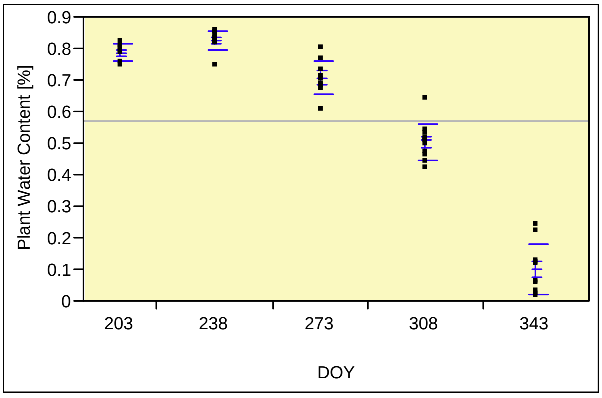
Canola



Chickpeas



Lentils



Wheat

Figure 6.22 Analysis of plant water content [%] over time [DOY]

Percentile plant water content correlation

In the correlation between percentile plant water and remote sensing data (Figure 6.23) wheat scored the highest R value with 0.73 for the DVI, followed by 0.72 for the near infrared band (band 3) and TVI. Canola equally showed a relationship with the vegetation indices; however the best R for canola was reached by a negative coefficient of -0.75 for the red band (band 2) (Figure 6.24 shows the linear regression for wheat and canola). Chickpeas did in this case not show high correlation results; this was explained that the plant water content is very similar and high on all investigated dates, while the remote sensing data changed with increased ground cover of chickpeas.

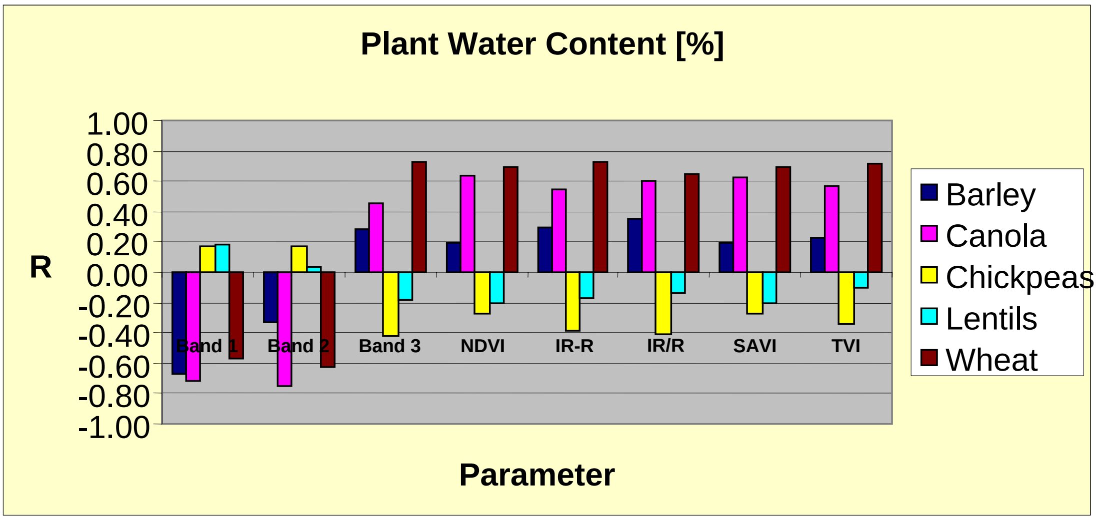


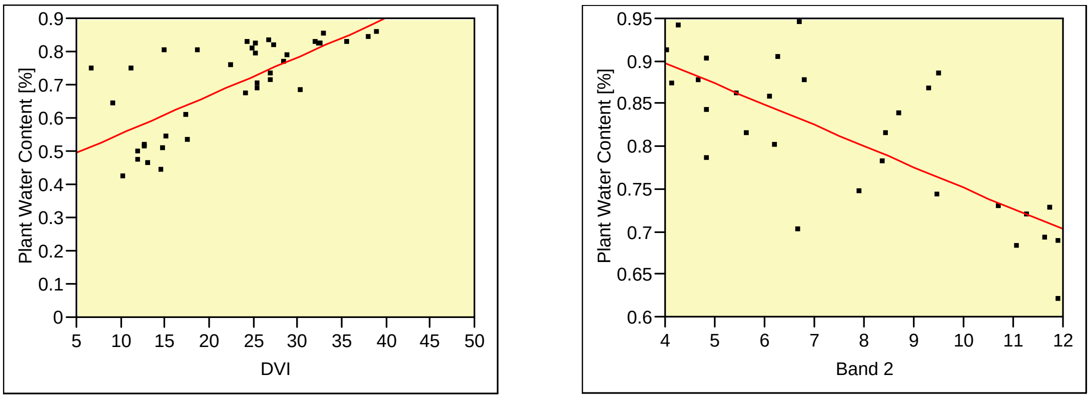
Figure 6.23 Correlation results for plant water content [%] and remote sensing parameters

Wheat

Plant Water Content [%] = 0.439194 + 0.0115472* DVI

Canola

Plant Water Content [%] = 0.9969874 - 0.0244896 *B2



R^2= 0.53

R^2= 0.56

Figure 6.24: Linear regressions for wheat and canola percentile plant water content and SPOT band 3

6.3.6 Volumetric soil moisture content

Volumetric soil moisture content field measurements

The volumetric soil moisture measurement determined the soil moisture in the top 5 centimetres. In optical remote sensing data the soil moisture content on the surface influences the signal brightness. Wet soils appeared darker (less reflectance) than dryer soils. Hence rainfall events changed the spectral characteristics of exposed soil. However when the optical satellites successfully acquired imagery in 1998, no rain clouds were present, nor was there recent rainfall. In the test area sufficient rain and therefore soil moisture was usually one of the most limiting factor for crop development and yield potential. Figure 6.25 shows the rainfall measured on farm 14 between the soil moisture measurements: the reading on DOY 203 for example indicated that 25 mm of rainfall were received since DOY 168. All paddocks showed very low volumetric soil moisture reading on DOY 273 (end of September) (Figure

6.25). This was due to little rainfall in the month prior (see rainfall recorded between soil moisture measurements by the farmer 14 in Figure 6.24), increased evaporation due to raising temperatures as well as major crop growth activity during that time. The December measurements (DOY 343) were higher than Novembers' (DOY 308), despite increased summer temperatures, as substantial rainfall occurred between the dates. Furthermore the crop was maturing and had less photosynthetic activity, hence evapotranspiration was reduced.

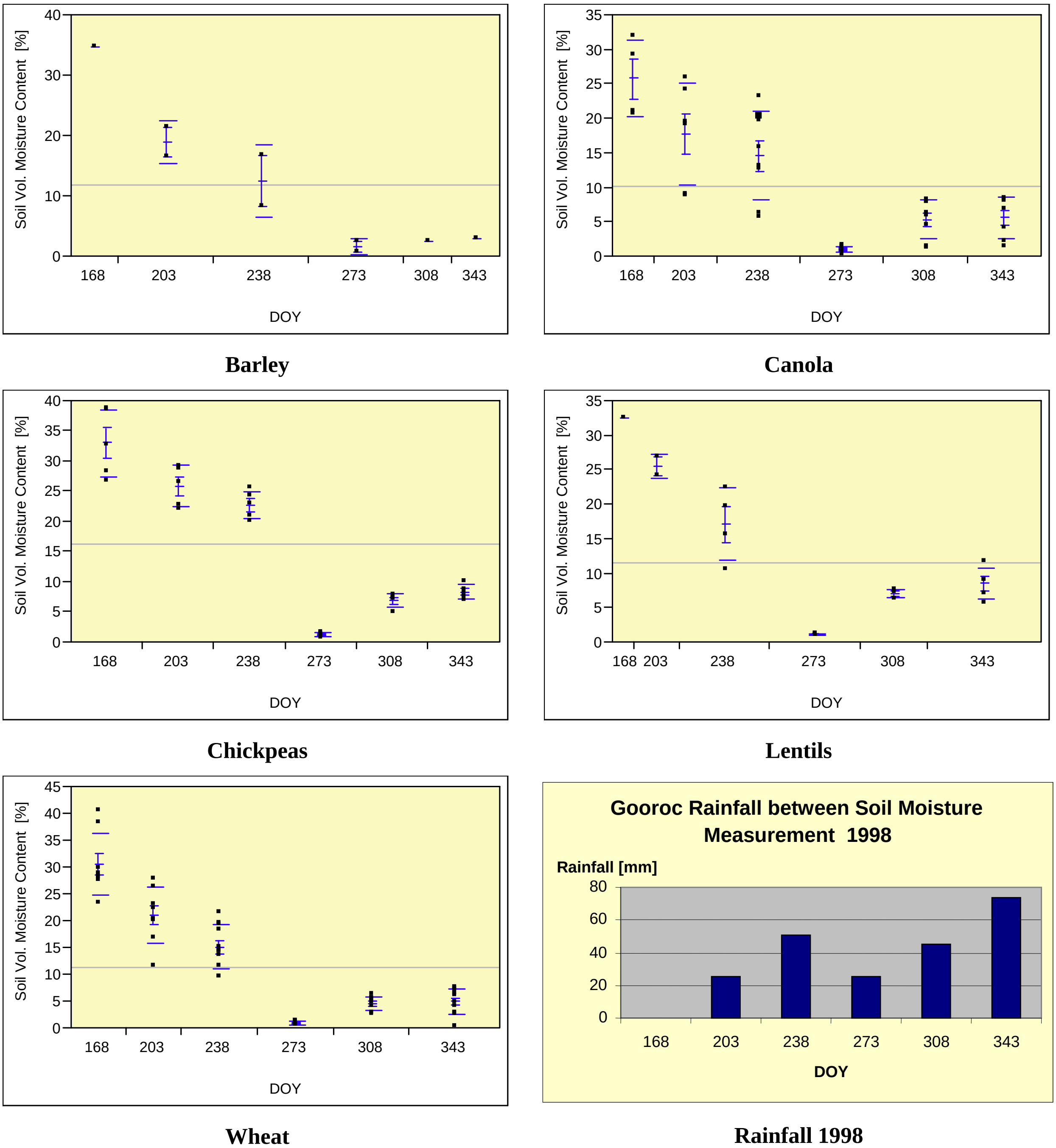


Figure 6.25 Analysis of volumetric soil moisture content [%], and rainfall over time [DOY]

To understand if plant parameters were related to volumetric soil moisture, pairwise correlations were calculated for all plant parameters and volumetric soil moisture (Table 6.2). It was observed that volumetric soil moisture was negatively related to plant height (Figure 6.26). This was partially due to the plants extracting water as they grew. However, most likely there was also the affect of time seen in the data; early in the season plants were shorter and soil moisture was higher than at the end of the season.

Table 6.2: Correlation results for volumetric soil moisture content and crop parameters

Variable	Plant Height [cm]	Green Biomass [g/m^2]	Dried Green Biomass [g/m^2]	Plant Water [g/m^2]	Plant Water Content [%]
Barley	-0.87	-0.86	-0.95	-0.73	0.80
Count	7	6	6	6	6
Signif Prob	0.011696357	0.027619372	0.003579423	0.096444938	0.057875236
Canola	-0.80	-0.47	-0.62	-0.29	0.36
Count	33	32	29	29	29
Signif Prob	0.0000000199	0.0072289466	0.0003216255	0.1235692280	0.0552929225
Chickpeas	-0.65	-0.38	-0.28	-0.43	0.04
Count	22	19	19	19	19
Signif Prob	0.0010751541	0.1047291038	0.2518426560	0.0641715004	0.8782433836
Lentils	-0.85	-0.47	-0.35	-0.47	0.12
Count	15	16	16	16	16
Signif Prob	0.0000608897	0.0690293777	0.1809960073	0.0671169727	0.6644581002
Wheat	-0.87	-0.59	-0.73	-0.16	0.48
Count	54	51	48	48	48
Signif Prob	0.0000000000	0.0000055389	0.0000000042	0.2715833219	0.0005442744

Volumetric soil moisture content correlation

Looking at the pairwise correlation (Figure 6.26), barley and canola had negative R coefficients, which were not significant, whereas wheat had non-significant positive R values for Band 3 and the vegetation indices. Best (negative) R values were achieved for the crops chickpeas and lentils, with the NDVI and SAVI respectively. The explanation therefore was that on chickpea and lentil fields canopy cover closure was later in the season than on wheat, barley and canola paddocks. Therefore most of the pixels had a substantial soil signal, which was influenced by soil moisture. Figure 6.27 gives the linear regression for volumetric soil moisture in chickpea fields and the NDVI.

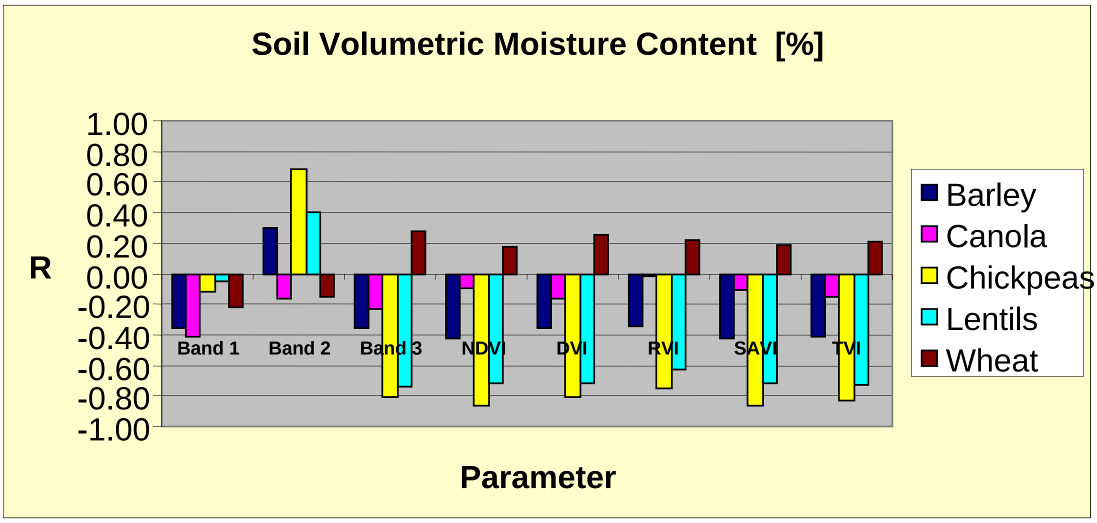


Figure 6.26 Correlation results for soil volumetric moisture content [%] and remote sensing parameters

Chickpeas

Vol. Soil Moisture Content [%] = 38.607571 - 55.662334 *NDVI; R^2= 0.743791

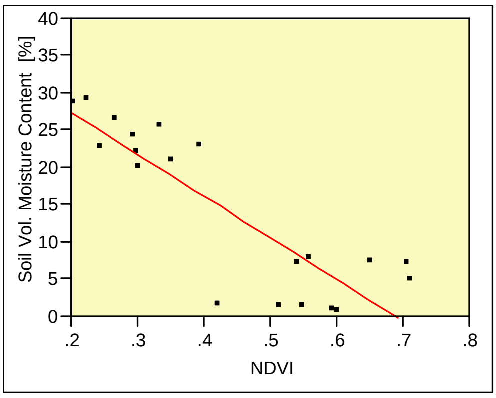


Figure 6.27: Linear regression for chickpeas percentile soil moisture content and SPOT NDVI

6.3.7 Available soil water in the depth 0-100 cm

Available soil water (ASW) field measurements

This measure integrated the available soil moisture from the surface to 1 metre depth. This was where the major root systems of the crops were located and water uptake occurred. It was investigated how available soil water was related to the various plant parameters by pairwise correlations. The results were given in Table 6.3.

The available soil water (0-100cm) on chickpea fields was observed to have a negative relationship with most plant parameters. Barley did not have enough sample points, in the canola crop the available soil water was related to percentile plant water content, lentils were (although not highly significant) related to dried green biomass and percentile plant water content. Wheat showed a relationship between the dried green biomass and ASW. In general the trend was that as the biomass increased throughout the season, the available soil moisture decreased. Wheat showed a negative R coefficient of -0.73 between ASW and plant height. The reason therefore was likely to be the growth spurt between DOY 238 and 273 that used up available soil water.

Table 6.3: Correlation results of available soil water [mm] and plant parameters

Variable	Plant Height [cm]	Green Biomass [g/m^2]	Dried Green Biomass [g/m^2]	Plant Water [g/m^2]	Plant Water Content [%]
Barley					
Count	2	1	1	1	1
Signif Prob					
Canola	-0.36	0.08	-0.38	0.21	0.67
Count	23	21	20	20	20
Signif Prob	0.0938496133	0.7411099345	0.1028348423	0.3723619275	0.0012123037
Chickpeas	-0.67	-0.71	-0.70	-0.68	0.61
Count	16	14	14	14	14
Signif Prob	0.0047976431	0.0046761890	0.0053832751	0.0080805668	0.0217358864
Lentils	-0.34	-0.63	-0.71	-0.52	0.69
Count	10	10	10	10	10
Signif Prob	0.3325856660	0.0508488250	0.0212760022	0.1267148595	0.0270668058
Wheat	-0.73	-0.52	-0.68	-0.15	0.37
Count	40	36	34	34	34
Signif Prob	0.0000000888	0.0012067170	0.0000094475	0.3879295439	0.0335332243

Figure 6.28 shows the available soil moisture measurements from the surface to one metre depth in 1998.

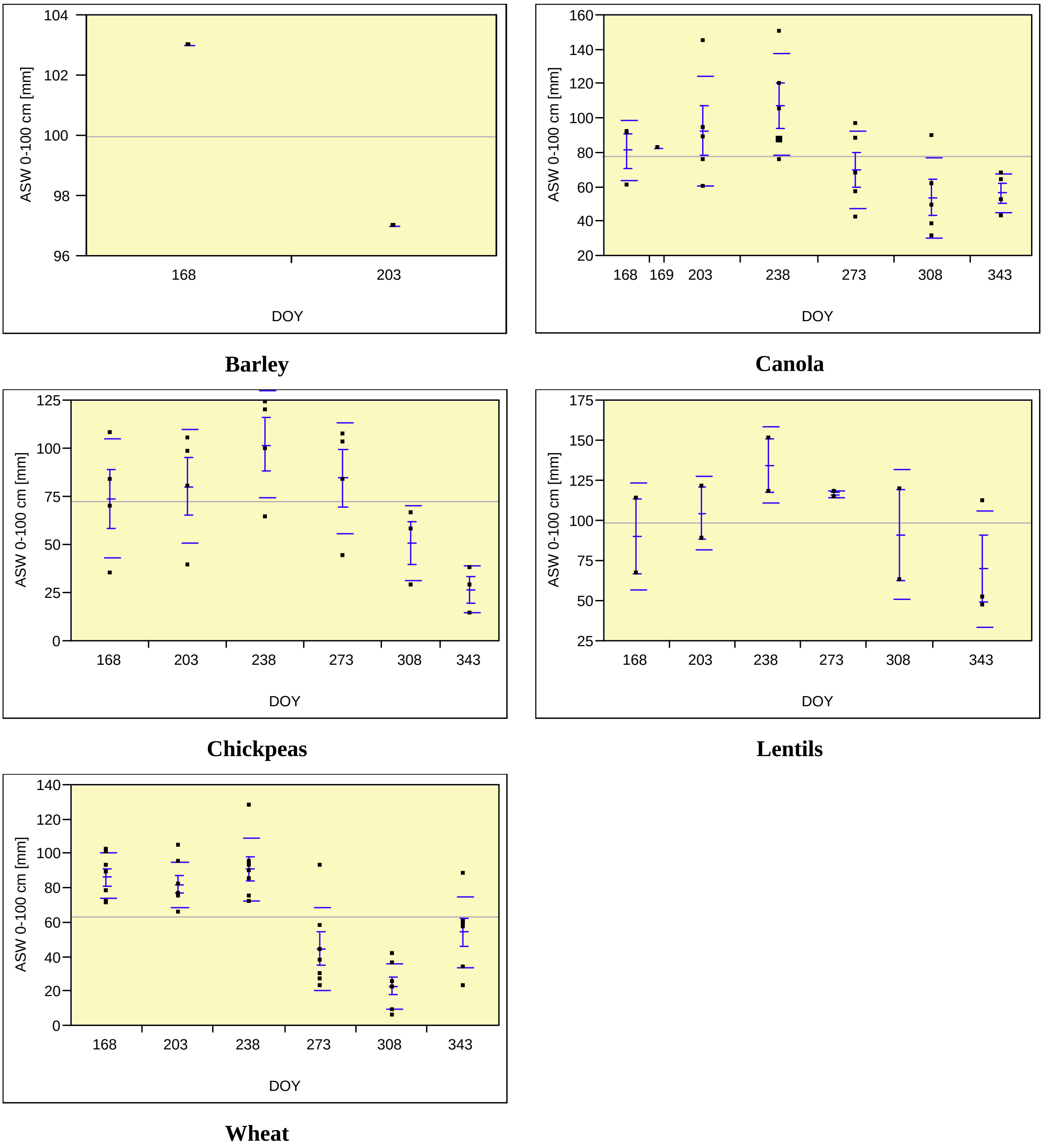


Figure 6.28 Analysis of available soil water [mm] over time [DOY]

Available soil water correlation

When observing the correlation trends for all crops (Figure 6.29), it was noticed that canola and wheat showed opposite behaviour to lentils and chickpeas. The R coefficients of canola and wheat were positive for band 3 and all the vegetation indices, while lentils and chickpeas exhibited negative R coefficients. The values for R were only moderate. Canola and wheat were sown earlier in the season and dried off toward the end of season; thus they were greener- (higher vegetation index) earlier when more ASW was available, while chickpeas and lentils develop and matured later. Chickpeas and lentils had a lower vegetation index earlier in the season (when there was more soil water available) and had a higher vegetation index later (November) when soil water diminished. Hence ASW was more related to the point in time rather than the absolute amount of soil water that could be modelled from the SPOT satellite remote sensing data.

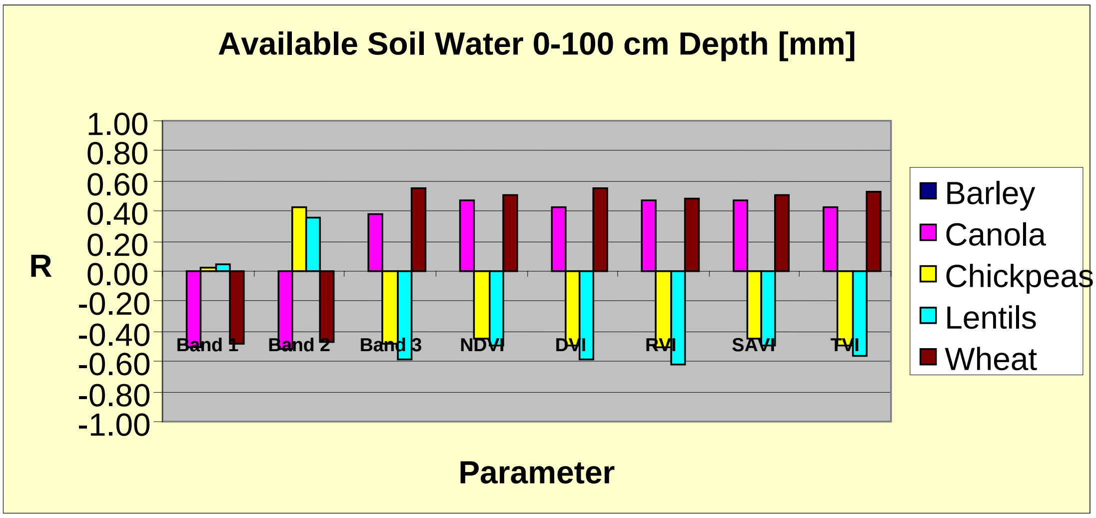


Figure 6.29: Correlation results of available soil water and remote sensing parameters

6.3.8 Correlation between field measurement parameters

To clarify if the plant parameters were interrelated, the correlation results between the different field measurement parameters were analysed (Table 6.4). Several strong correlations between the parameters could be observed. Barley (with only 6 sample points though) showed high R values for above ground dried green biomass and plant height (0.99), biomass [g/m^2] and plant water [g/m^2]. The later correlation result was also high for canola (0.98), chickpeas (0.97) and lentils (0.95). Wheat reached an R= 0.90 for above ground dried green biomass and plant height; most crops reached very high conformity for these two parameters. Noteworthy was the high correlation coefficient for most of the plant parameters of chickpeas. Only correlations with the percentile plant water content yielded less congruence.

Table 6.4: Correlation results of diverse plant parameters

Variable	Biomass [g/m^2]	Dried Biomass [g/m^2]	Dried Biomass [g/m^2]	Plant Water [g/m^2]	Plant Water [g/m^2]
by Variable	**Plant Height [cm]**	**Plant Height [cm]**	**Biomass [g/m^2]**	**Plant Height [cm]**	**Biomass [g/m^2]**
Barley	0.81	0.99	0.83	0.65	0.97
Count	6	6	6	6	6
Signif Prob	0.050941524	0.000220729	0.03901838	0.162704492	0.00127901
Canola	0.70	0.85	0.64	0.56	0.98
Count	31	28	29	28	29
Signif Prob	0.0000105314	0.0000000093	0.0001804042	0.0018474681	0.0000000000
Chickpeas	0.91	0.90	0.91	0.83	0.97
Count	20	20	20	20	20
Signif Prob	0.0000000338	0.0000000609	0.0000000168	0.0000050878	0.0000000000
Lentils	0.63	0.76	0.82	0.48	0.95
Count	15	15	17	15	17
Signif Prob	0.0120748318	0.0009797357	0.0000524945	0.0718060449	0.0000000028
Wheat	0.54	0.90	0.48	0.02	0.87
Count	49	45	48	45	48
Signif Prob	0.0000635886	0.0000000000	0.0005240366	0.9021319675	0.0000000000

Table 6.4: Correlation results of diverse plant parameters (continued)

Variable	Plant Water [g/m^2]	Plant Water [%]	Plant Water [%]	Plant Water [%]	Plant Water [%]
by Variable	**Dried Biomass [g/m^2]**	**Plant Height [cm]**	**Biomass [g/m^2]**	**Dried Biomass [g/m^2]**	**Plant Water [g/m^2]**
Barley	0.68	-0.85	-0.45	-0.86	-0.22
Count	6	6	6	6	6
Signif Prob	0.139705401	0.030367647	0.376333179	0.029704453	0.673965682
Canola	0.49	-0.43	0.15	-0.58	0.31
Count	29	28	29	29	29
Signif Prob	0.0074234625	0.0210456463	0.4522963761	0.0009287719	0.1060207379
Chickpeas	0.78	-0.44	-0.23	-0.54	-0.02
Count	20	20	20	20	20
Signif Prob	0.0000462670	0.0525454620	0.3231929355	0.0136822000	0.9359254282
Lentils	0.61	-0.46	-0.17	-0.62	0.08
Count	17	15	17	17	17
Signif Prob	0.0087458250	0.0845080300	0.5042534987	0.0080245907	0.7506430314
Wheat	-0.01	-0.67	0.19	-0.70	0.61
Count	48	45	48	48	48
Signif Prob	0.9507918911	0.0000004092	0.1980375586	0.0000000367	0.0000050932

Thus chickpea parameters were interrelated; the linear development of the crop parameters throughout the season were reflected in the remote sensing data and allowed the development of simple linear regression models for chickpeas. This linear behaviour of the chickpea spectral signature throughout the crop season was also observed in the 2001 SPOT data (Chapter 5, Figure 5.12), even though in 2001 chickpeas never reached their full potential. It is therefore expected that these regression functions can be transferred to other years; however, this will need to be tested in future research.

6.4 Discussion

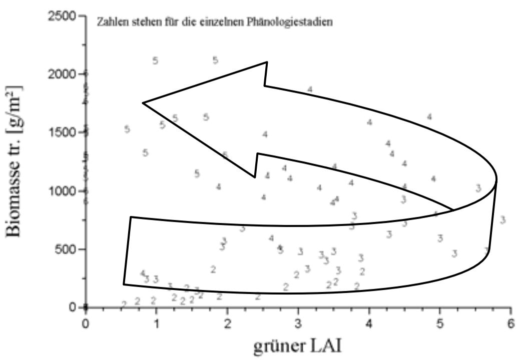
In this chapter the relationship between the field work measurements and remote sensing data were discussed. During six field trips in 1998, measurements of plant height, above ground green biomass, dried green biomass, spatial and percentile plant water content as well as volumetric soil moisture (0-5 cm) and available soil water (0-100cm) were taken. The spatial aspect of the field sampling and data extraction method from the SPOT satellite data were discussed. Furthermore due to the temporal offset between field data and satellite image acquisition a temporal adjustment of the SPOT satellite data was necessary; this was achieved by means of linear simulated satellite values. The vegetation indices used in the study were explained, in particular the modification of the triangular vegetation index (TVI) for SPOT data. The parameters that were measured during the field trips were graphically presented. For each of the five investigated crop types -barley, canola, chickpeas, lentils and wheat- the temporal development over the 1998 vegetation were shown, together with their mean and standard deviation, standard error mean and upper and lower 95% intervals. The Pearson Product moment coefficient R was calculated for pairwise correlations between the field data and SPOT satellite data: bands 1-3 and the derived vegetation indices (RVI, DVI, NDVI, SAVI and TVI).

It was found that good correlations could be obtained for some of the plant parameters, particular in chickpeas. For the parameter “plant height [cm]” chickpeas were highly correlated to SPOT Band 3 and all vegetation indices, with a best result of R=0.96 (band 3). A linear regression function with R^2= 0.91 was fitted. An above ground green biomass regression model was retrieved for chickpeas (R^2= 0.82, band 3) and lentils (R^2=0.70, band 3). Above ground green dried biomass could be estimated for chickpeas with a linear regression model with R^2=0.83 (Band 3). The parameter “plant water [g/m^2]” showed more or less strong correlations for all five crop types. A generic model for all crop types was fitted with R^2= 0.52 (band 3), as well as crop specific regression models for chickpeas (R^2=0.80, band 3), lentils (R^2=0.68, band 3) and canola (R^2=0.54, band 3). Percentile crop water content and the remote sensing data were not found to be related for chickpeas. However, wheat (R=0.73, DVI) and canola (R=-0.75, band 3) showed some correlations. Soil volumetric moisture content and the SPOT data showed negative correlations on chickpeas (R=-0.86, NDVI) and lentils (R=-0.74, Band 3). This was explained by the canopy closure of these two crops occurring later in the season; hence the soil component was contained in the pixel reflectance value. The reflectance value of the soil component was influenced by the soil moisture (in general wetter soil appears darker). The absolute amount of available soil water [mm] could not reliably be modelled from the satellite data.

The most noted result to report was that almost all field work parameters of chickpeas (other than percentile plant water content and available soil water) were highly related to the SPOT data. This was explained with the linear behaviour of the chickpea field measurements and the SPOT data over the season; chickpeas were the latest crop to be harvested of the five investigated crop types and therefore still vastly photosynthetically active on the last date (of the dataset used to calculate the correlations). Furthermore most plant parameters of chickpeas were linearly related to each other. Thus regression functions with good fits could be retrieved for most of the plant parameters of chickpeas. Ajai et al. (1983) measured spectral reflectance with a handheld spectrometer of irrigated and non-irrigated chickpeas in India. The reflectance was measured in two bands, red (665-685nm) and near infrared (815 to 825nm). The bands of the SPOT satellite used in this study were wider, with a red band from 610-680nm and a near infrared band at 780-890nm. Ajai et al. (1983) assessed the correlations of the red, near infrared band and the vegetation indices RVI and NDVI with leaf area index, chlorophyll content and dried green biomass. They found that the near infrared band, the RVI and NDVI were positively correlated to the crop parameters while the red band was negatively correlated. The results found in this study agreed with the results reported by Ajai et al. (1983). Ajai et al. (1983) found that the RVI was most stable and linear related while the NDVI and red band saturated for high chlorophyll measurements. The near infrared band on the other hand was also found to be linear related to chlorophyll. The correlation results found for dried green biomass and the near infrared band agree in both studies with 0.90 (Ajai et al., 1983) and 0.91 (this study). However the correlation results for the red band of both studies vary (-0.61 this study and -0.94 in Ajai’s study). This can be explained by the fact that Ajai et al. (1983) used a narrow red band centred around the chlorophyll a and b absorption maximum (Gradinaru et al. 1998) for their handheld spectrometer measurements while the SPOT red band was wider and thus not as specific. The effects of the spectral band selection consequently also affected the results of the vegetation index correlations where Ajai et al. (1983) obtained better results than found in this study. When Ajai et al. (1983) compared the vegetation indices of water stressed and non stressed (irrigated) chickpeas, they found the RVI to be up to 30% more sensitive to water content than the NDVI. Agreement was found in this study where greater sensitivity in similar proportions to percentile water content was found for the RVI when compared to the NDVI.

Crops other than chickpeas matured and turned yellow in senescence (in particular wheat and barley and to a lesser extent canola) which was observed in the satellite data and in the field. The results of correlation between satellite data and plant parameters for these crops might be improved by devising two regression functions for the crops instead of one; one regression would cover the time frame before the VI maximum and another thereafter. A similar approach was discussed by Ridao et al. (1998) in their estimation of the fraction of absorbed photosynthetically active radiation (fAPAR) in semi-leafless peas and in faba beans. They found that after reaching complete canopy development, yellowing of senescent leaves decreases the vegetation index values more than the fraction of absorbed radiation, and proposed that two different vegetation index –fAPAR relationships should be considered in the pre- and post-LAI maximum phases of the crop cycle of both species. To test the approach proposed by Ridao et al (1998) field and satellite data obtained at more frequent time intervals are needed than the one presented in this work; thus this approach will need to be tested in future research.

Demircan (1995) observed the phenological development of dried biomass from cereals in relation to measured green leaf area index (LAI) in Germany (Figure 6.30) and derived biomass estimates (R=0.95) with a regression function incorporating the product from date, total LAI and phenology (he related measured LAI and LAI from Landsat TM NDVI for cereals with R=0.86). A similar path was observed in the cereal development of this study when dried biomass was related to the satellite data (TVI in Figure 6.31).



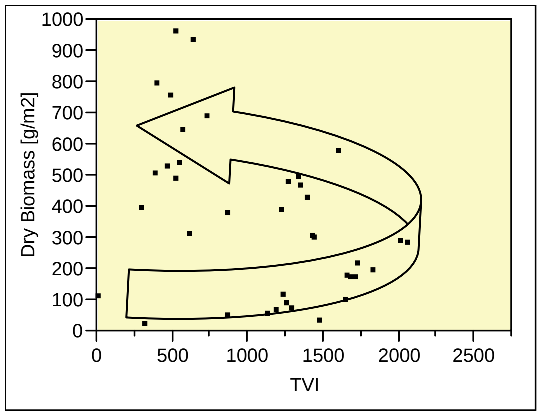


Figure 6.30: Dry biomass related to green LAI in cereals (from Demircan, 1995; arrow added)

Figure 6.31: Dry biomass related to vegetation index TVI

Note the amounts of dried biomass (g/m2) in figures 6.30 and 6.31. Australian fields produced less than half the amount of biomass than the German site. Dryland farming in Australia is much less intensive than most parts of Europe and North America.

6.5 Conclusions

SPOT satellite data were related to measured crop parameters. The best correlation results were obtained by band 3 and not by the vegetation indices. This result was attributed to the wide bandwidth of the red band of the SPOT satellite which did not focus on the chlorophyll a and b absorption peaks. Consequently vegetation indices using the red band also resulted in inferior results to the near infrared band. Another reason that band 3 performed well was the stable radiometric and atmospheric calibration results that could be achieved for the data sets. The DVI and the by the author modified TVI performed in most cases in this study better than the NDVI.

When estimating crop parameters from crops other than chickpeas, simple linear regression models yielded only moderate results. The vegetation indices followed a parabolic path as the crops progressed in their phenological development (increase to a plateau at maximal green biomass and ground cover and then decrease with senescence). A similar pattern is repeated when relating the vegetation indices to the measured crop parameters. Hence the linear regression functions should be separated into two functions before and after vegetation index maximum similar to a solution proposed by Ridao et al (1998). Satellite data with higher temporal frequency are needed to reliably establish the regression functions. Another approach would be to derive non-linear functions, incorporating agro-meteorological models, the Day of Year (DOY) and the regional phenology stage of each crop type at the given day of parameter estimation. As previously discussed in Chapter 5, a seasonal adjustment subject to the Southern Oscillation Index would need to be considered in this equation.

For chickpeas good relationship (with an R^2 above 0.8) between some plant parameter and the remote sensing parameters were found. This was attributed to the linear behaviour of spectral properties and the crop parameter development throughout the season. The derived linear regression functions for chickpeas are summarized in Table 6.5.

Table 6.5: Chickpea linear regression functions for selected crop parameters

Linear Regression	R^2
Plant Height [cm] = -22.55153 + 1.5986302 * Band 3	0.91
Above Ground Green Biomass [g/m^2] = -1106.794 + 54.718622 * Band 3	0.82
Dried Green Biomass [g/m^2] = -326.2893 + 15.673842 * Band 3	0.83
Plant Water [g/m^2] = -780.5049 + 39.04478 * Band 3	0.80

It is expected that the regression models produced by the research can be transferred to other years if calibrated SPOT data are used. This will however need to be tested. If sensors with system configurations (wavelength, band width) other than SPOT are used, the models most likely need to be adjusted.

7. Crop yield models derived from yield maps and SPOT satellite data

7. 1 Introduction

Profitable farming is maximizing returns (yields of appropriate quality) while minimizing expenses and maintaining long term environmental sustainability. Hence farmers would like to have a yield map of their paddocks as early in the "growing" season as possible. This information allows the farmer to allocate investment funds (in the form of fertilizers, chemicals etc.) to areas in the paddock where it will bring financial return. Knowing reliable yield targets will also enable the farmer to maintain soil nutrient levels at appropriate levels - ensuring there is sufficient supply for crop demands without surplus leaching into water tables. A further benefit of yield maps prior to harvest is that farmers can adjust their crop insurance fittingly. Therefore the research presented in this chapter examined the question as to whether crop yield could be modelled quantitatively using SPOT imagery. These models could then be used to produce yield maps from satellite imagery prior to harvest.

7.2 Methods

Yield maps that were obtained by precision farming equipment on board of a combine harvester were compared to SPOT satellite data. It was investigated if satellite data contained information that could be used to estimate crop yields in advance. Two methods were applied (see Figure 7.1 for a schema of steps used in the modelling). Each single satellite acquisition date was compared to the yield map collected at the end of the season, during harvest. Obviously, events that happened to the crop after the satellite acquisition date could not be accounted for in this method. Therefore, data obtained from the accumulated sums of the satellite bands and various vegetation indices from multiple dates were also tested. Furthermore, the dataset containing the satellite data of the whole crop season was investigated with a stepwise regression modelling approach (barley was not included in the study due to a lack of data) to test and improve the reliability of the derived models of crop yield.

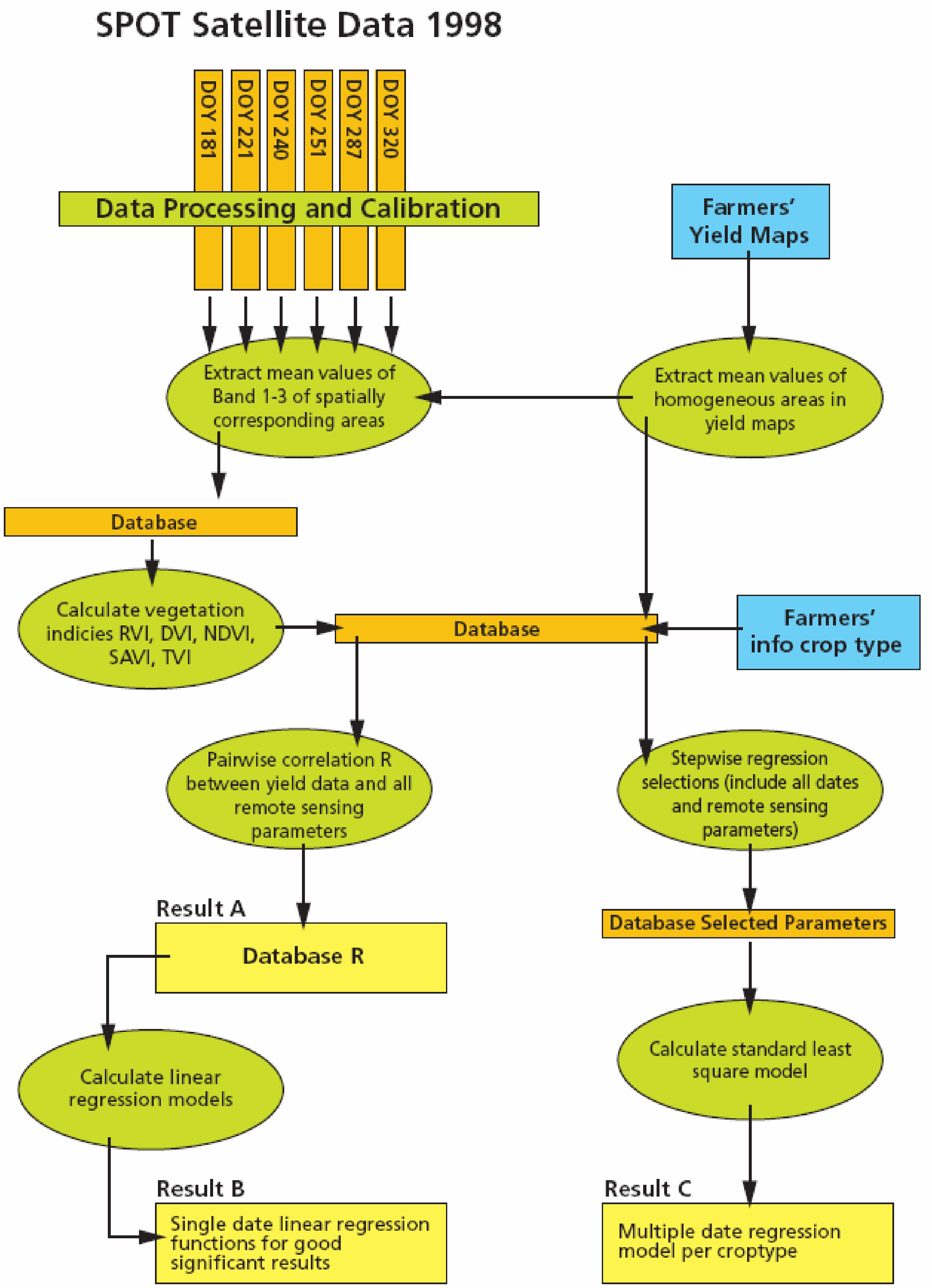


Figure 7.1: Overview of steps employed to derive yield regression models from satellite data

The flow chart gives an overview of the processes used in this chapter to derive the results. Orange fields symbolize databases, blue indicate that farmers supplied the information. Yellow fields mark the results and green circles show the processing that was applied to compute the results.

7.2.1 Data

The yield maps were pre-processed as described in Chapter 4. For some fields, only partial areas were able to be mapped with the yield monitor. Table 4.4 gives an overview of the yield maps available from Farm 14. Due to circumstances beyond the control of the study, no barley yield maps were able to be derived (army worm infestation resulting in fallow management). For similar reasons, yield maps for only two relatively small areas of neighbouring lentil fields (no yield monitor data were recorded in the other part of the paddock at harvesting) could be generated.

7.2.2 Data extraction

Yield monitors record yield during harvest. However, due to current limitations in this technology, the yield maps derived from this data source may have inherent errors. These errors can arise because of random and systematic errors such as delays between harvest and recording of yield data; actual harvest width varies from programmed harvest width in yield monitor; passing over areas which were already harvested; turning areas and many others; A detailed summary of these issues is given by: Blackmore, 2000; Blackmore and Moore, 1999; Vansichen and De Baerdemaeker., 1992; Blackmore and Marshall, 1996; Missotten et al., 1996; Thylen et al., 1996; Reitz, 1997; Stafford et al., 1997; Juerschik and Giebel, 1999, Nissen and Söderström, 1999; Colvin and Arslan, 2000; Arslan and Colvin, 2002; Grisso et al., 2002; Reyniers, 2003. It was therefore decided not to attempt to correlate the whole yield map pixel by pixel with the satellite imagery, but to choose the centre area of homogeneous yield areas within the field and to extract a mean value for the yield data (Figure 7.2). The mean value of the same area of interest (AOI) was extracted from the satellite data (Figure 7.3), and these data formed the basis for investigating correlations between crop yield and the satellite imagery.

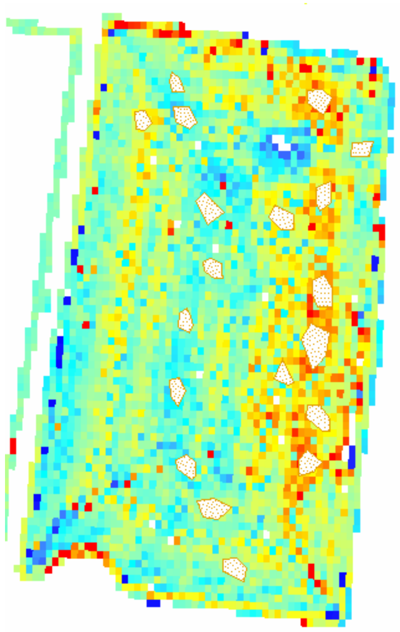


Figure 7.2: Yield map canola, Adelines South field with AOIs

Figure 7.3: SPOT RGB Adelines South field, 16/11/1998 (DOY 320) with AOIs

In total, the mean values of 164 AOI were extracted from four canola fields. 129 chickpea AOI were investigated from four chickpea paddocks; only 16 AOI could be extracted from two partial lentil fields. 249 AOI were sampled from the seven wheat yield maps data and analysed.

7.2.3 Vegetation Indices and accumulated sums

The vegetation indices NDVI, RVI, DVI, SAVI and TVI were calculated from the satellite data as described in Chapter 6 (6.2.3). Furthermore the accumulated sums of satellite data parameters were calculated from multiple image dates (4, 5 and 6 dates) as accumulated sums have been documented to be related to crop yields (Quarmby et al., 1993; Maselli et al., 1993; Cabezon and Taylor, 1994; Hayes and Decker, 1996). Thus in the nomenclature described in the results section of this chapter, "SUM (4) Band 3", for example, means that the mean reflectance values derived of an AOI for band 3 were added from 9/8/98 and 28/8/98 and 8/9/98 and 14/10/98. SUM (5) NDVI added the NDVI values from 9/8/98 and 28/8/98 and 8/9/98 and 14/10/98 and 16/11/98. SUM TVI summed up all the TVI values that were available in the dataset (from 30/6/98 and 9/8/98 and 28/8/98 and 8/9/98 and 14/10/98 and 16/11/98).

7.2.4 Statistical analysis

The yield data were statistically analysed with respect to their distribution parameters, such as number of samples, mean, standard deviation, medium, range, percentiles, skewness and kurtosis, etc.

It was tested at what accuracies crop yields could be estimated from satellite imagery at a single date and with accumulated sums in the season. Therefore the extracted AOI values from the yield data and SPOT satellite data were correlated by means of calculating the Pearson Product Moment coefficient R for the datasets. The results were summarized for each crop type in an overview graph.

Furthermore, it was investigated if accuracies could be improved when including all the satellite images in the dataset. Two stepwise forward regression models were calculated. One included the satellite bands 1-3, derived vegetation indices and various accumulated sums of all acquisition dates, while the other was a simplified version, containing only band 1-3. The probability control to enter the model was 0.25 and the probability to leave was 0.1. The step history was recorded. The abbreviations in the step history tables were (Sall et al. 2005):

> *Signif. Prob* is the probability of obtaining, by chance alone, a correlation with greater absolute value than the computed value if no linear relationship exists between the *X* and *Y* variables.
>
> *SS:* is the reduction in the error (residual) SS if the term is entered into the model or the increase in the error SS if the term is removed from the model. Sequential Tests shows the reduction in residual sum of squares as each effect is entered into the fit.
>
> *RSquare:* is the proportion of the variation in the response that can be attributed to terms in the model rather than to random error.
>
> *Cp:* is Mallow's C_p criterion for selecting a model. It is an alternative measure of total squared error defined as Cp= (SSEp/s2) – (N-2p); where s^2 is the MSE for the full model and SSE_p is the sum-of-squares error for a model with *p* variables, including the intercept. Note that p is the number of *x*-variables+1.

Lastly standard least square models were fitted to the parameters which were selected in the stepwise models.

7.3 Results

7.3.1 Canola

The canola yield data were close to a normal distribution. A description of the yield data is documented in Figure 7.4.

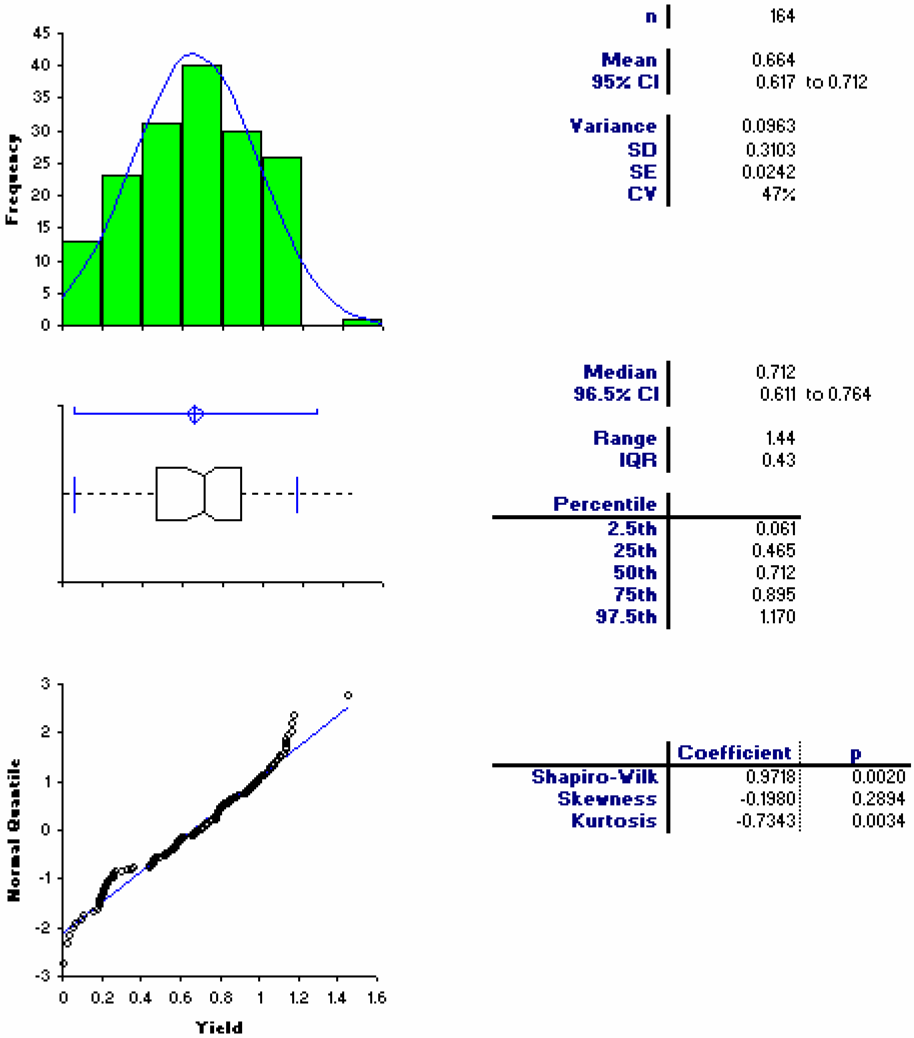


Figure 7.4: Description of the distribution of the canola yield data (top = frequency histogram, centre = box-whisker plot highlighting possible near- & far- outliers, bottom = normal probability plot

Correlation between the remote sensing parameters and the yield data of canola were tested. It was noted that as early as DOY 221 (9 August 1998) an R of greater than 0.8 was reached with band 3 and with most of the vegetation indices. The accuracies for the vegetation indices and band 3 declined with approach to harvest. Models including SPOT Band 1 and 2 generated inferior results throughout the crop season. Most of the accumulated sums produced an R coefficient of greater than 0.8 (other than band 1 and 2). Figure 7.5 and 7.6 show a summary of the results of the pairwise correlation; the data tables are attached in Appendices I and J.

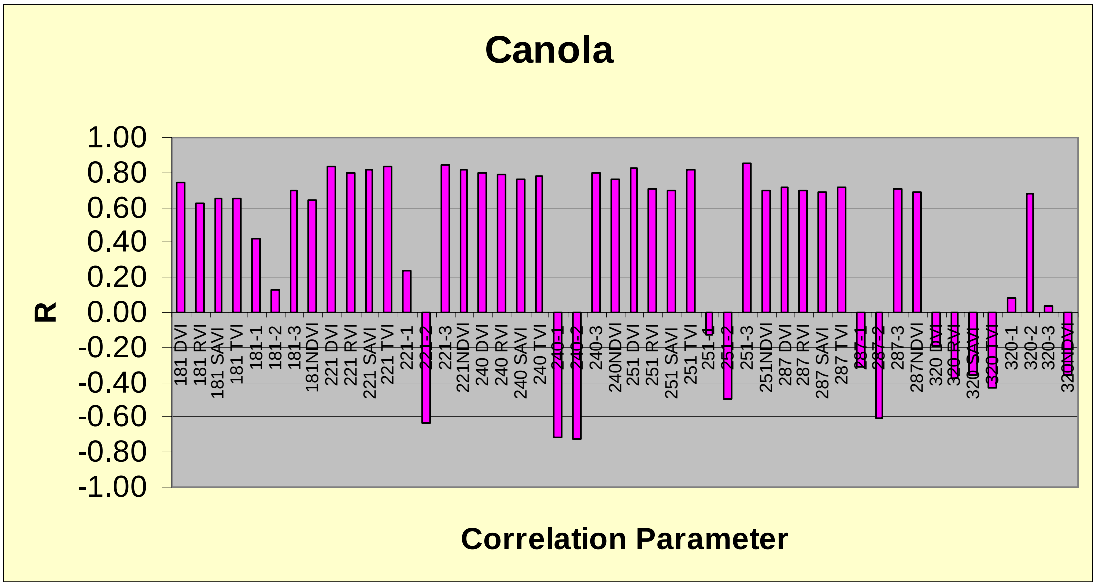


Figure 7.5: Overview of canola yield and satellite parameter correlation results

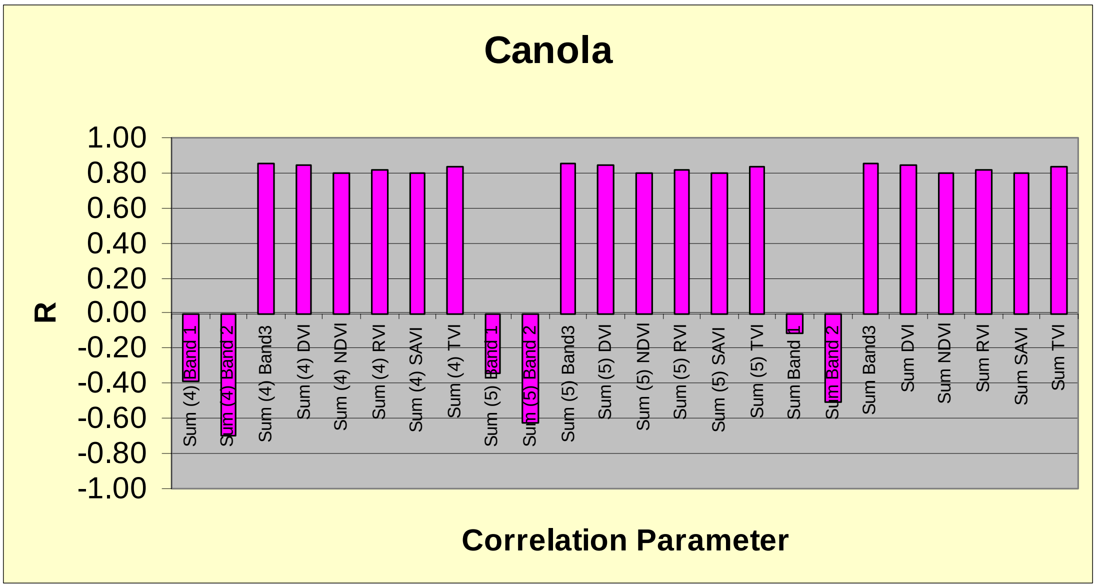
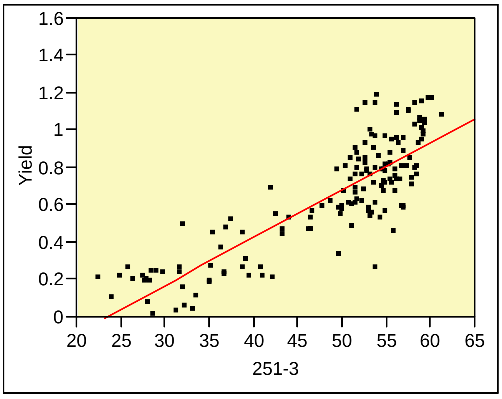


Figure 7.6: Continuation of overview of canola correlation results

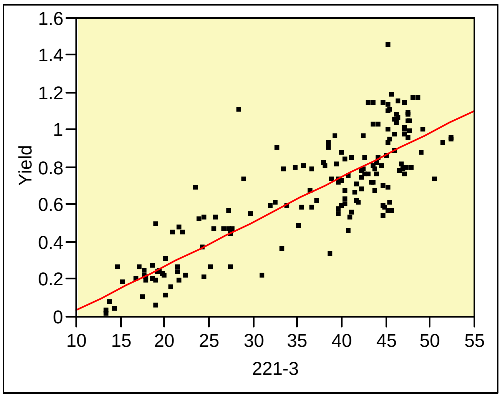
A linear regression function was fitted for the best single date result on DOY 251 (band 3, R= 0.85) and the earliest good correlation result on DOY 221 (band 3, R= 0.84). An R^2 of 0.72 and 0.71 was reached, respectively (Figure 7.7).

Yield Canola = -0.587965 + 0.025356 * B3 (DOY251)



R^2= 0.720192

Yield Canola = -0.200267 + 0.0238039 *B3 (DOY221)



R^2= 0.709748

Figure 7.7: Linear Regression Functions for canola on DOY 251 and DOY 221

Furthermore, a forward stepwise regression model was calculated for the combined dataset of canola. In the step history 14 parameters were selected by the model, which were used to calculate a standard least square model. The model had an accuracy of R^2= 0.88 (Table 7.1, Figure 7.8). The model with only Bands 1-3 had an accuracy of R^2= 0.87 (Table 7.2, Figure 7.9); it was simpler and yielded a similar result.

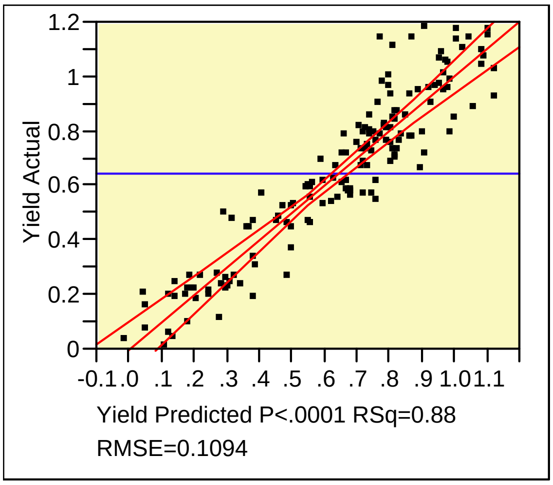
Table 7.1: Step history for multitemporal canola yield estimate model (see text for explanation)

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	Sum Band3	0.0000	10.21439	0.7299	145.95	2
2	240-3	0.0000	0.606315	0.7733	100.31	3
3	320-2	0.0000	0.506365	0.8095	62.517	4
4	181-3	0.0021	0.163989	0.8212	51.631	5
5	240-1	0.0068	0.120505	0.8298	44.161	6
6	Sum (4) DVI	0.0000	0.301909	0.8514	22.437	7
7	221NDVI	0.0641	0.048118	0.8548	20.655	8
8	181 TVI	0.0169	0.078115	0.8604	16.517	9
9	287-1	0.0820	0.040479	0.8633	15.336	10
10	251 SAVI	0.0953	0.036742	0.8659	14.449	11
11	221 SAVI	0.0125	0.080323	0.8716	10.137	12
12	221-1	0.0451	0.05025	0.8752	8.1881	13
13	181-2	0.0591	0.043722	0.8784	6.7524	14
14	320NDVI	0.1445	0.025782	0.8802	6.7263	15

Table 7.2: Step history for multitemporal canola yield estimate model, (Band 1-3)

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	251-3	0.0000	10.07786	0.7202	141.33	2
2	251-2	0.0000	0.698364	0.7701	91.188	3
3	240-3	0.0076	0.148932	0.7807	82.069	4
4	221-2	0.0024	0.183197	0.7938	70.391	5
5	320-3	0.0033	0.163065	0.8055	60.216	6
6	240-1	0.0000	0.389438	0.8333	33.141	7
7	320-2	0.0001	0.237844	0.8503	17.383	8
8	287-3	0.0257	0.070422	0.8553	14.125	9
9	287-1	0.0229	0.071225	0.8604	10.808	10
10	221-1	0.0341	0.060164	0.8647	8.3159	11
11	287-2	0.1673	0.025156	0.8665	8.4377	12

Stepwise yield model with all parameters

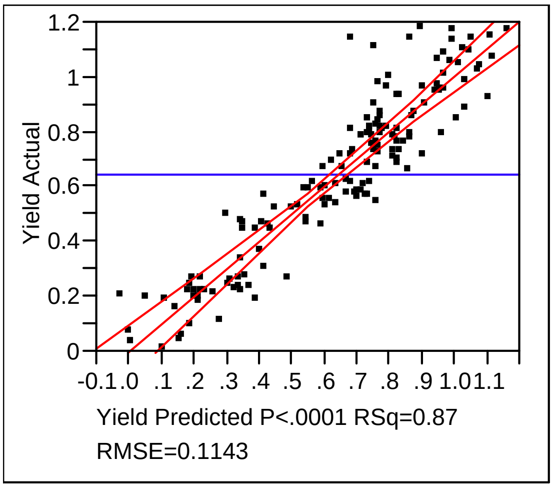


RSquare	0.880207
RSquare Adj	0.868228
Root Mean Square Error	0.109424
Mean of Response	0.645614
Observations (or Sum Wgts)	155

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-2.684833	0.54587	-4.92	<.0001
181-2	-0.051442	0.025725	-2.00	0.0475
181-3	-0.037193	0.018688	-1.99	0.0485
181 TVI	-0.000644	0.000235	-2.74	0.0069
221-1	0.0539155	0.022164	2.43	0.0163
221NDVI	115.83673	31.66006	3.66	0.0004
221 SAVI	-77.35807	21.28504	-3.63	0.0004
240-1	-0.11341	0.026652	-4.26	<.0001
240-3	-0.04268	0.006023	-7.09	<.0001
251 SAVI	-0.813561	0.249987	-3.25	0.0014
287-1	-0.08828	0.032216	-2.74	0.0069
320-2	0.0486163	0.033412	1.46	0.1479
320NDVI	-1.318262	0.898365	-1.47	0.1445
Sum Band3	0.0544312	0.010525	5.17	<.0001
Sum (4) DVI	-0.030874	0.009568	-3.23	0.0016

Figure 7.8: Predicted versus actual canola crop yield, all parameters

Stepwise yield model with SPOT Band 1-3



RSquare	0.866534
RSquare Adj	0.856268
Root Mean Square Error	0.114282
Mean of Response	0.645614
Observations (or Sum Wgts)	155

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-2.119549	0.33503	-6.33	<.0001
221-1	0.04593	0.020284	2.26	0.0251
221-2	-0.034386	0.011804	-2.91	0.0042
240-1	-0.128327	0.02663	-4.82	<.0001
240-3	-0.014402	0.003256	-4.42	<.0001
251-2	0.0815169	0.015692	5.19	<.0001
251-3	0.0230048	0.004932	4.66	<.0001
287-1	-0.108823	0.037823	-2.88	0.0046
287-2	0.0399305	0.028772	1.39	0.1673
287-3	0.0195519	0.006068	3.22	0.0016
320-2	0.0827365	0.017702	4.67	<.0001
320-3	0.0353255	0.005989	5.90	<.0001

Figure 7.9: Predicted versus actual canola crop yield, band 1-3 only

7.3.2 Chickpeas

The chickpea yield data were close to normal distribution. Figure 7.10 summarizes the description of the yield data.

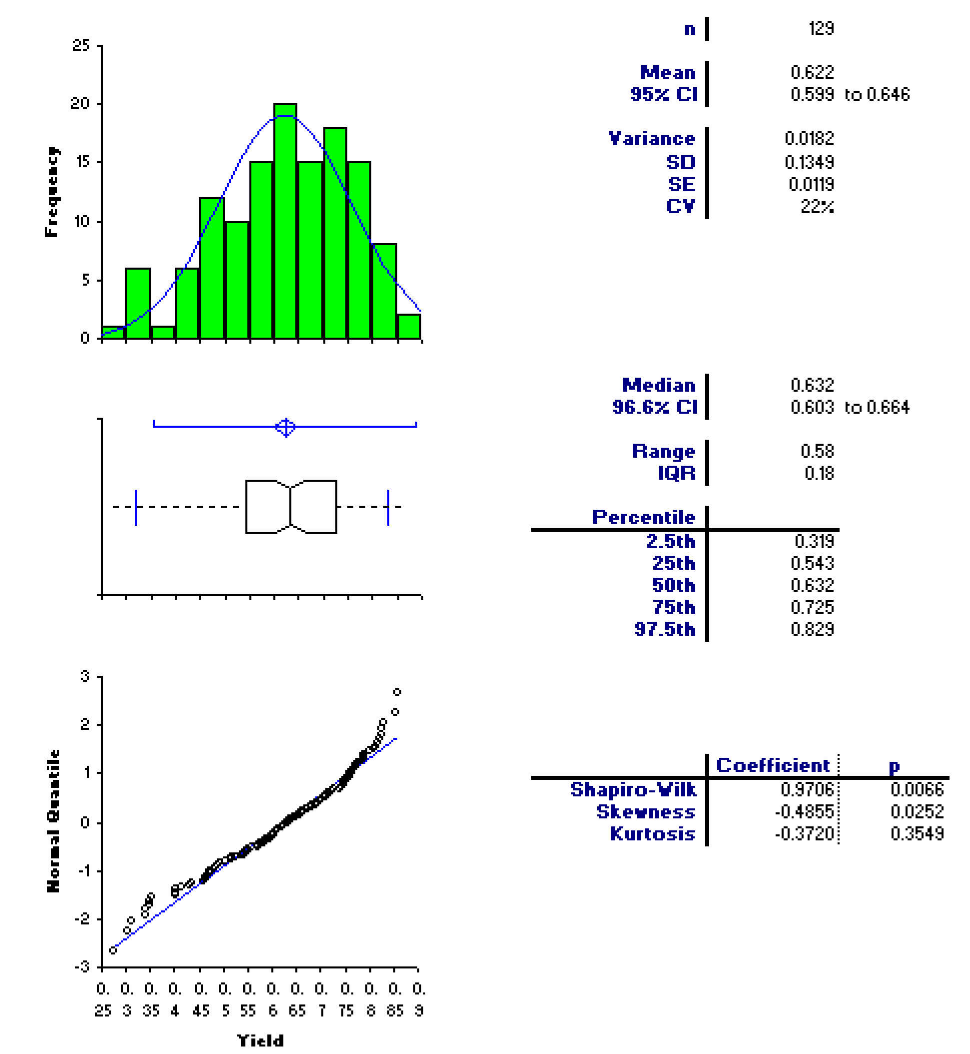


Figure 7.10: Description of the distribution of the chickpea yield data

The correlations of the chickpea yield data and the satellite parameters were tested. In the single date (Figure 7.11) and accumulated sums (Figure 7.12) pairwise correlations it was noted that the best results had a Pearson correlation coefficient R just above 0.4, and -0.4, respectively. It was mainly reached by bands 1 and 2.

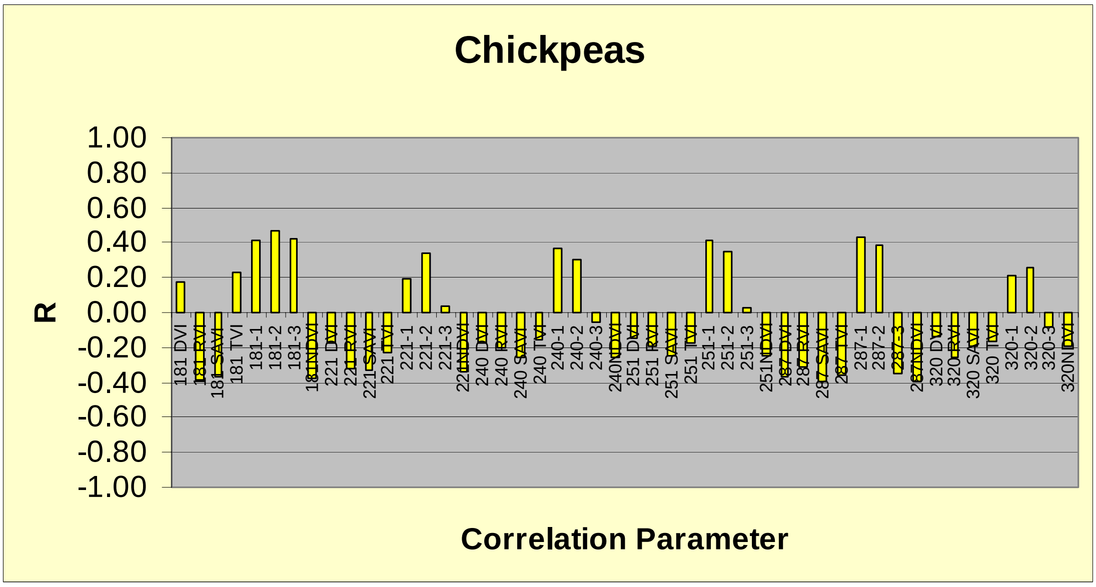


Figure 7.11: Overview of chickpea yield and satellite parameter correlation results

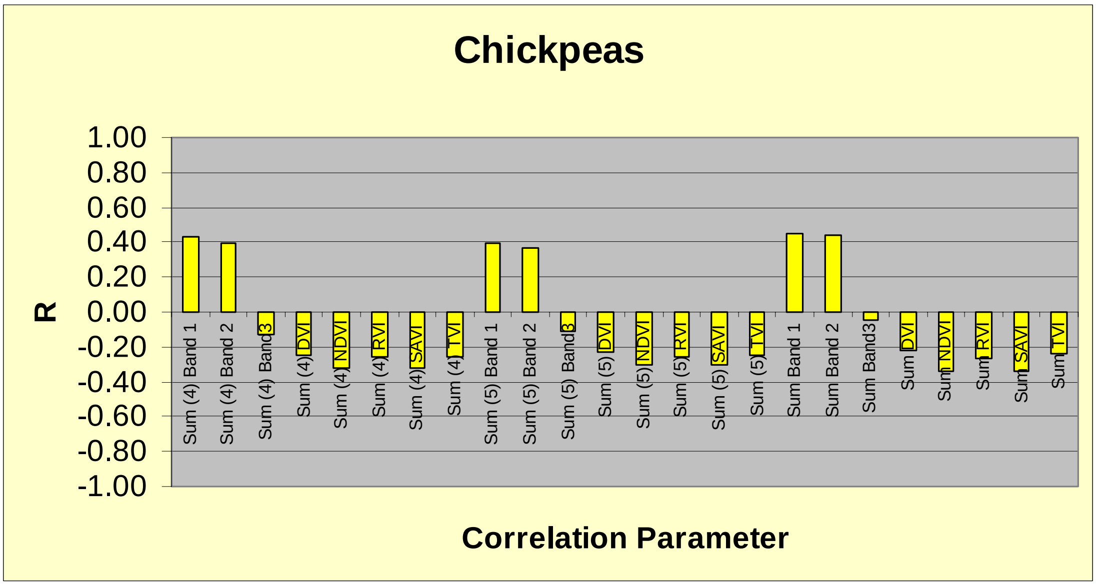


Figure 7.12: Continuation of overview of chickpea correlation results

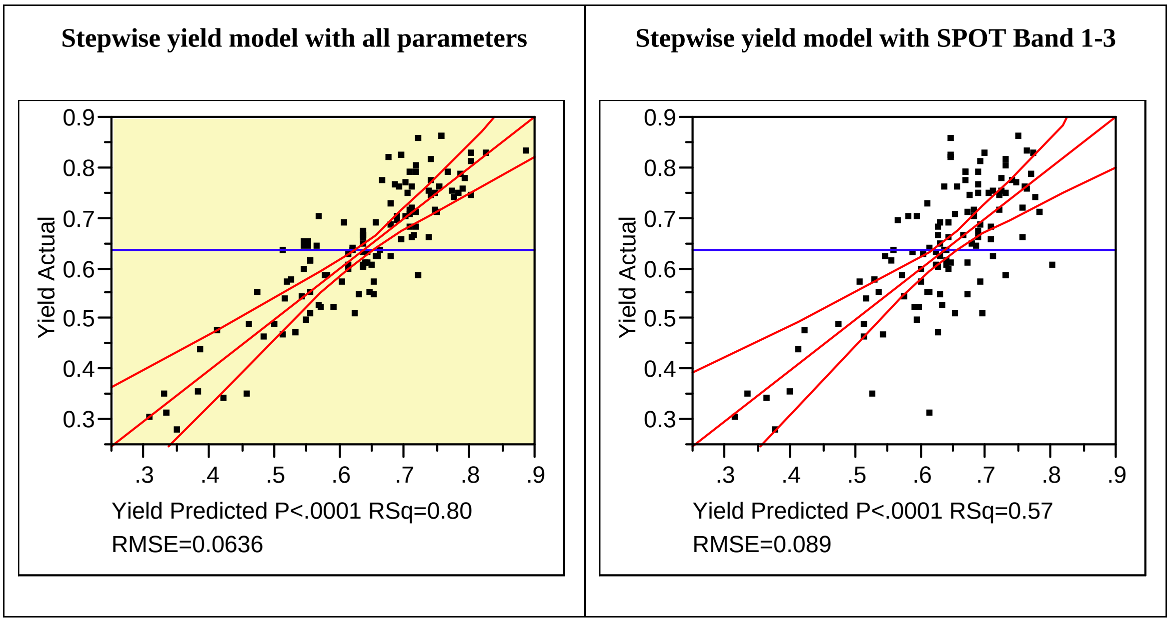
Furthermore, a forward stepwise regression model was calculated for the combined dataset of chickpeas. In the step history 18 parameters were selected by the model, which were used to calculate a standard least square model. The model had an accuracy of R^2= 0.80 (Table 7.3, Figure 7.13). The model with only Bands 1-3 had an accuracy of R^2= 0.57 (Table 7.4, Figure 7.14); other than canola the simplified model for chickpeas was substantially worse than the model incorporating all vegetation indices.

Table 7.3: Step history for chickpea yield estimate model

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	181-2	0.0000	0.406743	0.2205	261.03	2
2	Sum (4) DVI	0.0000	0.288479	0.3770	189.18	3
3	221-1	0.0029	0.09156	0.4266	167.74	4
4	320-1	0.0095	0.065287	0.4620	153.02	5
5	Sum Band 1	0.0045	0.073743	0.5020	136.14	6
6	240 RVI	0.0189	0.047595	0.5278	125.96	7
7	240 SAVI	0.0230	0.042812	0.5510	117	8
8	251 RVI	0.0275	0.038687	0.5720	109.09	9
9	251NDVI	0.0002	0.102952	0.6278	84.733	10
10	320-3	0.0095	0.044818	0.6521	75.259	11
11	320 RVI	0.0000	0.111103	0.7124	48.815	12
12	240 DVI	0.0067	0.0385	0.7332	40.958	13
13	240NDVI	0.0040	0.040421	0.7552	32.609	14
14	287-3	0.0405	0.019414	0.7657	29.639	15
15	Sum (4) Band 1	0.0363	0.019576	0.7763	26.627	16
16	320 DVI	0.0488	0.016786	0.7854	24.329	17
17	320 SAVI	0.0644	0.014365	0.7932	22.652	18
18	240-3	0.1371	0.009104	0.7981	22.321	19

Table 7.4: Step history for chickpea yield estimate model (Band 1-3)

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	251-3	0.0000	10.07786	0.7202	141.33	2
2	251-2	0.0000	0.698364	0.7701	91.188	3
3	240-3	0.0076	0.148932	0.7807	82.069	4
4	221-2	0.0024	0.183197	0.7938	70.391	5
5	320-3	0.0033	0.163065	0.8055	60.216	6
6	240-1	0.0000	0.389438	0.8333	33.141	7
7	320-2	0.0001	0.237844	0.8503	17.383	8
8	287-3	0.0257	0.070422	0.8553	14.125	9
9	287-1	0.0229	0.071225	0.8604	10.808	10
10	221-1	0.0341	0.060164	0.8647	8.3159	11
11	287-2	0.1673	0.025156	0.8665	8.4377	12



RSquare	0.798121
RSquare Adj	0.758623
Root Mean Square Error	0.063615
Mean of Response	0.638572
Observations (or Sum Wgts)	111

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.3817616	3.237477	1.35	0.1792
181-2	-0.004295	0.031786	-0.14	0.8928
221-1	-0.03187	0.035609	-0.89	0.3731
240-3	0.1448809	0.096593	1.50	0.1371
240NDVI	-778.8176	249.6267	-3.12	0.0024
240 RVI	1.666305	0.545148	3.06	0.0029
240 DVI	-0.725108	0.243857	-2.97	0.0038
240 SAVI	535.73803	171.5421	3.12	0.0024
251NDVI	-9.352862	1.758138	-5.32	<.0001
251 RVI	1.6125499	0.297202	5.43	<.0001
287-3	-0.040974	0.015414	-2.66	0.0093
320-1	-0.17708	0.054309	-3.26	0.0016
320-3	-0.315978	0.146662	-2.15	0.0338
320 RVI	-0.38267	0.078577	-4.87	<.0001
320 DVI	0.4617772	0.187691	2.46	0.0157
320 SAVI	-6.264188	2.948763	-2.12	0.0363
Sum Band 1	0.1088619	0.042719	2.55	0.0125
Sum (4) Band 1	-0.112866	0.048153	-2.34	0.0212
Sum (4) DVI	0.0193727	0.010602	1.83	0.0709

Figure 7.13: Predicted versus actual chickpea crop yield, all parameters

RSquare	0.566378
RSquare Adj	0.527739
Root Mean Square Error	0.088983
Mean of Response	0.638572
Observations (or Sum Wgts)	111

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.800443	0.436935	1.83	0.0699
181-1	0.0938694	0.048235	1.95	0.0544
181-2	0.0869606	0.045909	1.89	0.0611
181-3	-0.026126	0.022543	-1.16	0.2492
221-1	-0.091417	0.027466	-3.33	0.0012
251-1	0.0409532	0.022398	1.83	0.0704
287-3	-0.01663	0.004159	-4.00	0.0001
320-1	-0.164158	0.037075	-4.43	<.0001
320-2	0.0952259	0.027862	3.42	0.0009
320-3	0.0157163	0.006454	2.44	0.0166

Figure 7.14: Predicted versus actual chickpea crop yield, band 1-3 only

7.3.3 Lentils

Only 16 data points were available for the lentil yield dataset. The distribution was almost normal (Figure 7.15). The robustness of the lentil models need to be verified on a larger dataset; however lentils were included in this study nevertheless to show the trends observed.

The pairwise correlation of the remote sensing parameters (band 1-3, vegetation indices and accumulated sums) and the yield data of canola were tested. It was noted that the strength of predictions could be achieved after DOY 251 (about 0.8, Figure 7.16); in particularly the accumulated sums yielded results >0.8 (Figure 7.17). It was noted that all accumulated sums of the RVI had high R values (0.88, 0.89). The best RVI single date result was reached on DOY 287 with R=0.86; the linear regression function thereof is included in Figure 7.18.

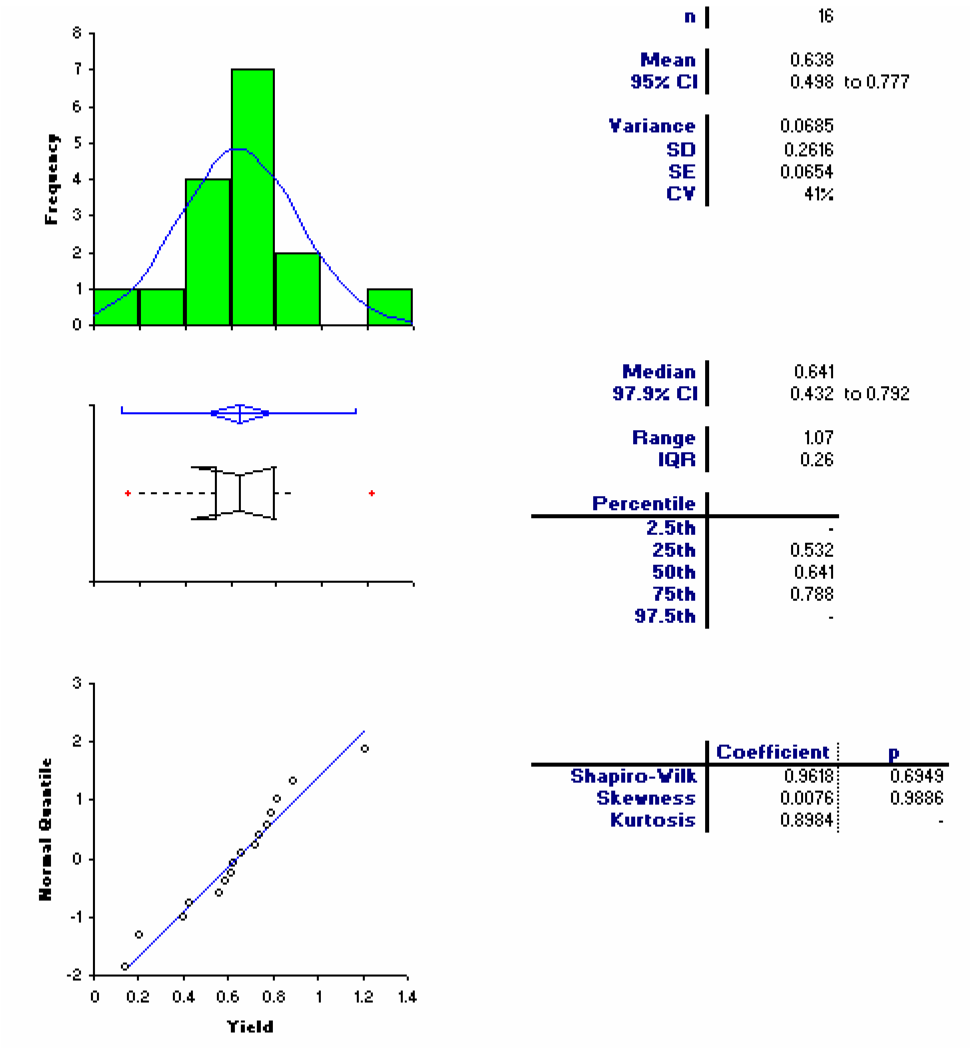


Figure 7.15: Description of the distribution of the lentil yield data

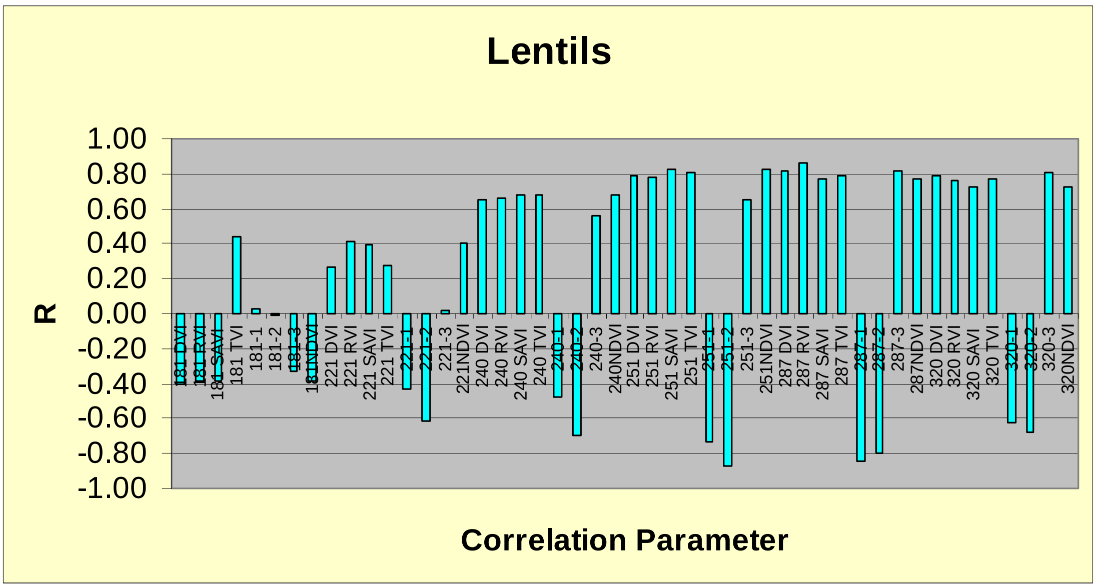


Figure 7.16: Overview of lentil yield and satellite parameter correlation results

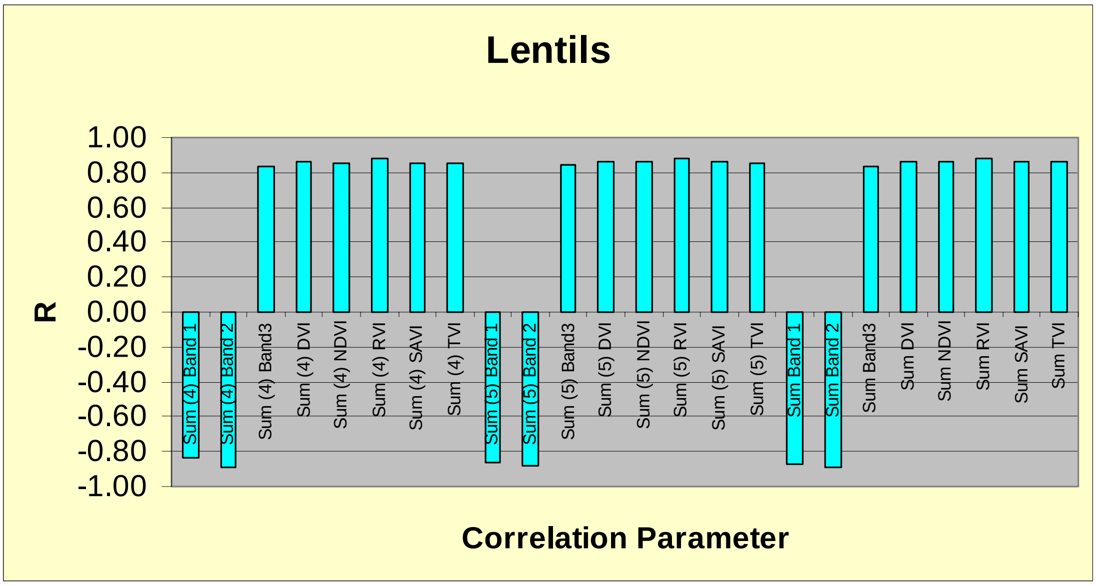
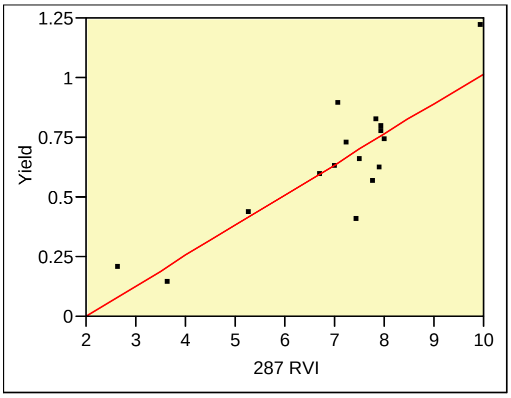


Figure 7.17: Continuation of overview of lentil correlation results

Yield Lentils = -0.250608 + 0.1269492 287 RVI



R2= 0.743273

Figure 7.18: Linear regression function for lentil on DOY 287

Furthermore, a forward stepwise parameter selection was calculated for the dataset containing all remote sensing parameters and the dataset using only band 1-3 of all available dates. The step histories were included in Table 7.5 and 7.6, respectively. The selected parameters were applied to a least square regression model. The results were 0.86 and 0.84, respectively. Details on the models are found in Figure 7.19 and 7.20.

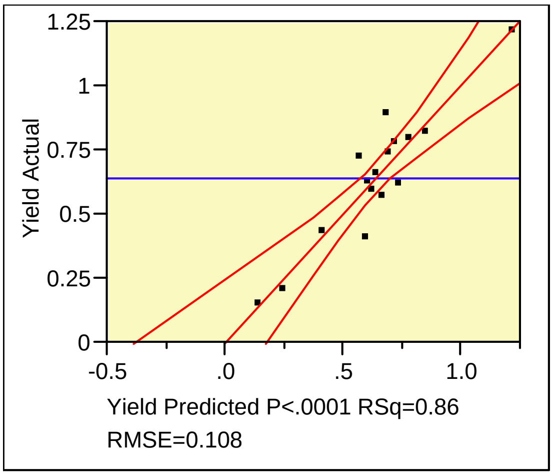
Table 7.5: Step history for multitemporal lentil yield estimate model

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	Sum Band 2	0.0000	0.814406	0.7931	.	2
2	181-1	0.0797	0.046206	0.8381	.	3
3	Sum (5) SAVI	0.1586	0.026348	0.8637	.	4

Table 7.6: Step history for multitemporal lentil yield estimate model (Band 1-3)

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	251-2	0.0000	0.77735	0.7570	.	2
2	287-1	0.0266	0.080979	0.8359	.	3

Stepwise yield model with all parameters

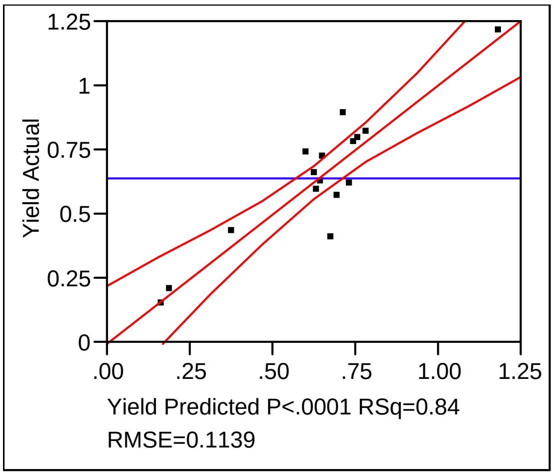


RSquare	0.863744
RSquare Adj	0.82968
Root Mean Square Error	0.107981
Mean of Response	0.637795
Observations (or Sum Wgts)	16

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-0.023173	3.270029	-0.01	0.9945
181-1	-0.40807	0.164741	-2.48	0.0291
Sum Band 2	0.0018944	0.041809	0.05	0.9646
Sum (5) SAVI	0.6700185	0.445714	1.50	0.1586

Figure 7.19: Predicted versus actual lentil crop yield, all parameters

Stepwise yield model with SPOT Band 1-3



RSquare	0.835863
RSquare Adj	0.810611
Root Mean Square Error	0.113865
Mean of Response	0.637795
Observations (or Sum Wgts)	16

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.357185	0.359841	9.33	<.0001
251-2	-0.135921	0.04268	-3.18	0.0072
287-1	-0.202448	0.081006	-2.50	0.0266

Figure 7.20: Predicted versus actual lentil crop yield, band 1-3 only

Comparing the results of the stepwise models to the single date and accumulated sums pairwise correlation results, it was found that the results could not be improved with a stepwise model. These findings were contradictory to the results obtained from all the other crop types investigated in this study. It needs to be determined if the same result can also be found in a larger lentil dataset.

7.3.4 Wheat

The wheat data were not normally distributed, but showed a bimodal distribution (Figure 7.21). It was thought that this distribution was mainly due to late frost in October 1998, which resulted in substantial yield losses in the area (see Figure 7.26 for the distribution excluding paddocks noted to have incurred frost-damaged).

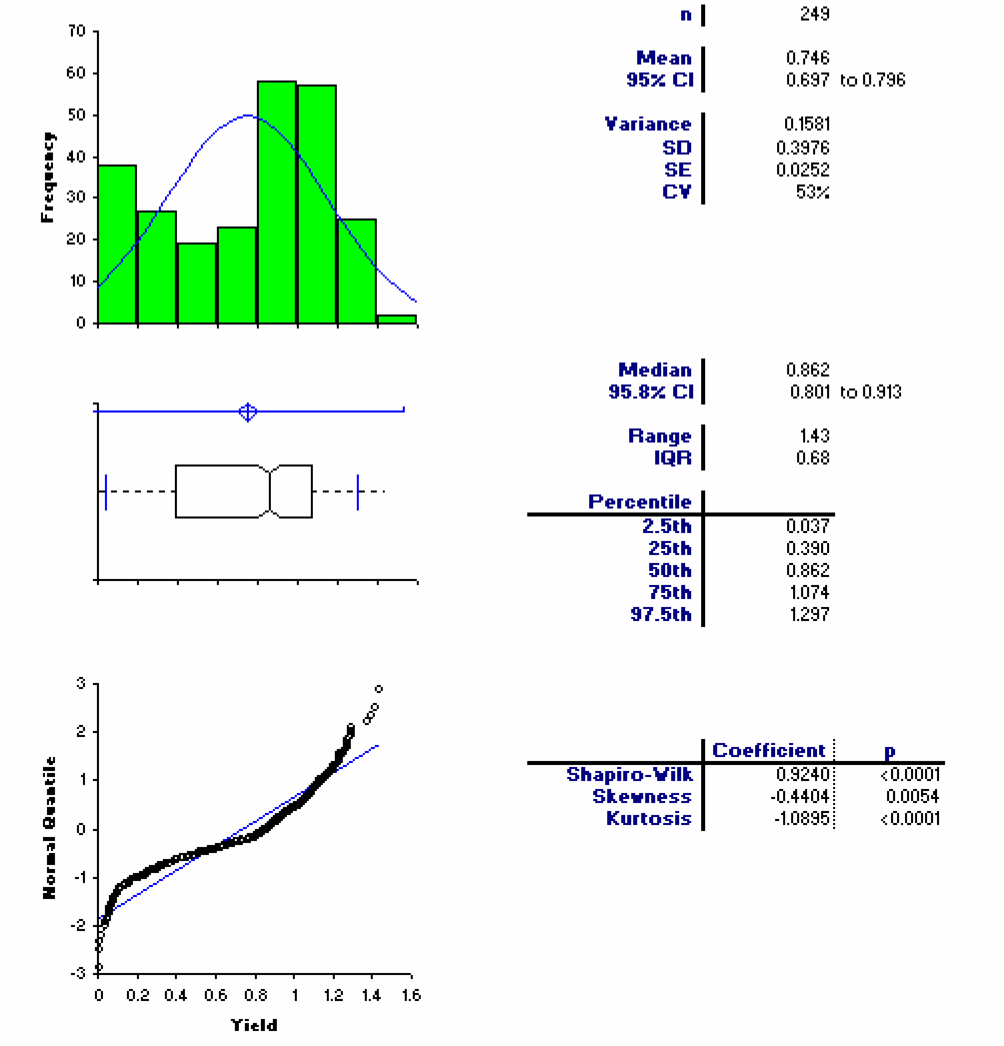


Figure 7.21: Description of the distribution of the wheat yield data

The pairwise correlation of the remote sensing parameters (band 1-3, vegetation indices and accumulated sums) and the yield data of all wheat paddocks was tested. It was noted that the correlation result of single dates showed weak congruence until the frost event in late October (0.2-0.3 in most cases, Figure 7.22), and only slight improvements after the frost event at the mid November satellite acquisition (approx.

0.4). All accumulated sums showed weak results (approx 0.2 and weaker in most cases, Figure 7.23).

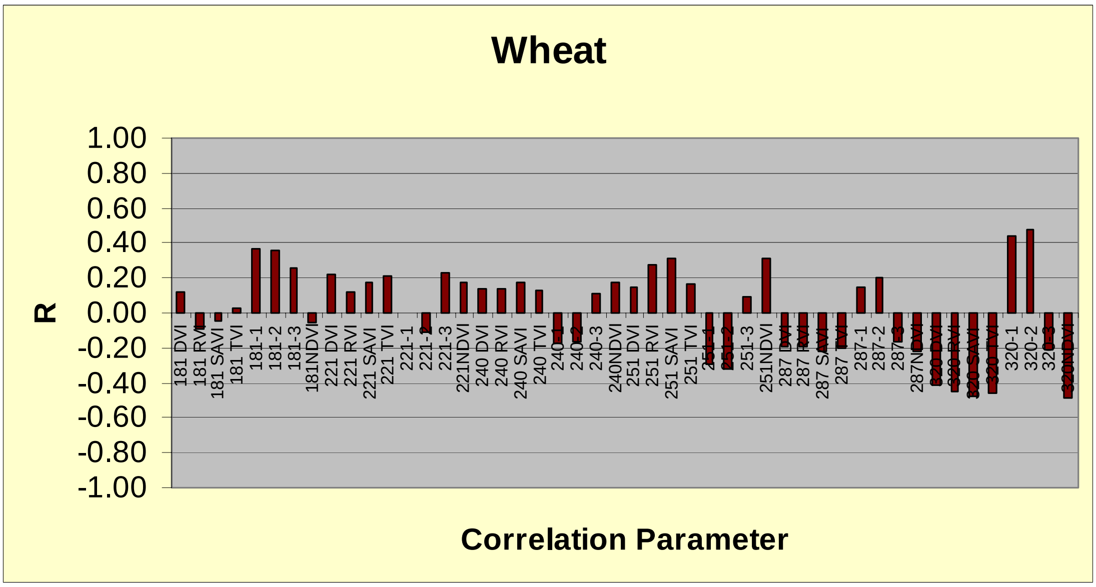


Figure 7.22: Overview of wheat yield and satellite parameter correlation results

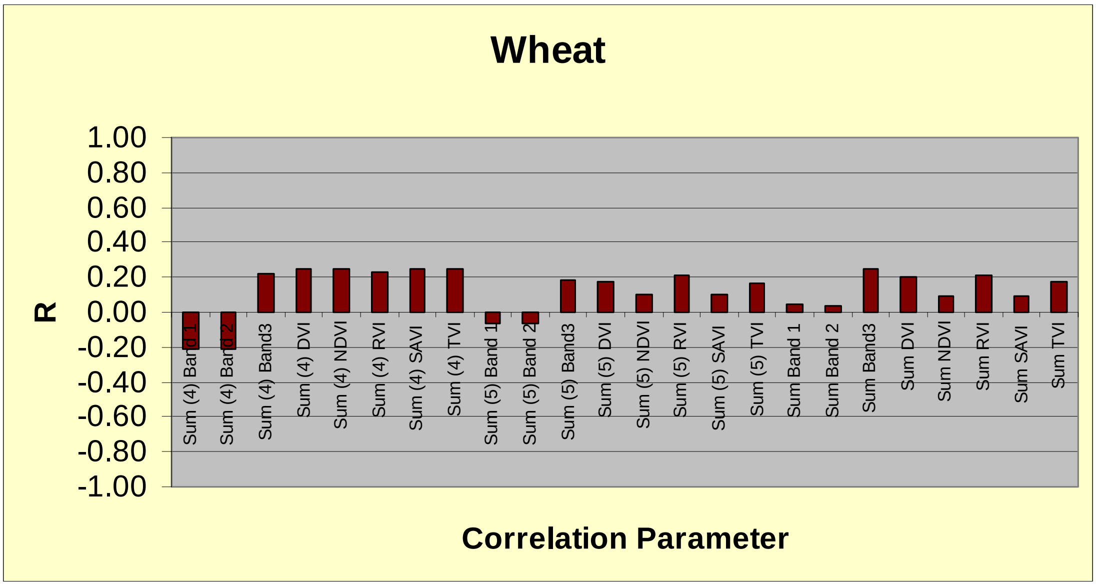


Figure 7.23: Continuation of overview of wheat correlation results

Furthermore, a forward stepwise regression model was calculated for the dataset of all satellite parameters and all wheat paddocks. In the step history 14 parameters were selected by the model (Table 7.7), which were used to calculate a standard least square model. The model had an accuracy of R^2= 0.62 (Figure 7.24). The model using only Bands 1-3 had 11 parameters selected and the standard least square model reached an accuracy of R^2= 0.53 (Table 7.8, Figure 7.25).

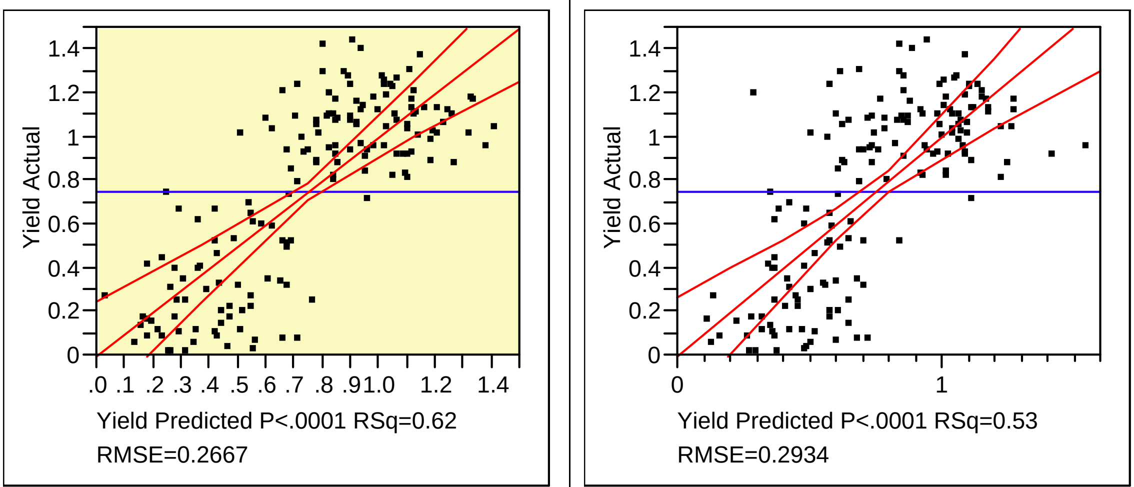
Table 7.7: Step history for multitemporal wheat yield estimate model

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	320NDVI	0.0000	6.217132	0.2278	166.08	2
2	287 RVI	0.0000	6.164692	0.4536	73.883	3
3	181-2	0.0000	1.69599	0.5158	49.968	4
4	320 RVI	0.0156	0.490553	0.5337	44.472	5
5	287 DVI	0.0245	0.41263	0.5488	40.167	6
6	240-3	0.0314	0.368236	0.5623	36.541	7
7	251-1	0.1048	0.205648	0.5699	35.398	8
8	221-2	0.1005	0.208515	0.5775	34.212	9
9	221NDVI	0.0996	0.207361	0.5851	33.044	10
10	287-1	0.1493	0.157491	0.5909	32.637	11
11	Sum RVI	0.2165	0.115056	0.5951	32.879	12
12	Sum (5) TVI	0.0661	0.251822	0.6043	31.031	13
13	287 TVI	0.1953	0.123806	0.6089	31.139	14
14	240 SAVI	0.0250	0.364876	0.6222	27.564	15

Table 7.8: Step history for multitemporal wheat yield estimate model (Band 1-3)

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	320-2	0.0000	5.052171	0.1851	97.516	2
2	251-2	0.0000	4.294721	0.3424	50.568	3
3	287-3	0.0193	0.62057	0.3652	45.495	4
4	320-3	0.0000	2.105359	0.4423	23.499	5
5	240-3	0.0352	0.433453	0.4582	20.559	6
6	181-2	0.0092	0.642768	0.4817	15.233	7
7	287-2	0.0235	0.471268	0.4990	11.862	8
8	221-3	0.0472	0.353225	0.5119	9.8359	9
9	221-2	0.1475	0.185635	0.5187	9.7202	10
10	251-1	0.1008	0.236116	0.5274	9.029	11
11	251-3	0.1702	0.163483	0.5334	9.1658	12

Stepwise yield model with all parameters | **Stepwise yield model with SPOT Band 1-3**



RSquare	0.62222
RSquare Adj	0.585745
Root Mean Square Error	0.266674

RSquare	0.533376
RSquare Adj	0.498695
Root Mean Square Error	0.293358

Mean of Response	0.754663
Observations (or Sum Wgts)	160

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-1.33409	1.838625	-0.73	0.4693
181-2	-0.056057	0.049325	-1.14	0.2576
221-2	0.2409668	0.102277	2.36	0.0198
221NDVI	1.6646126	1.876688	0.89	0.3766
240-3	-0.069638	0.019488	-3.57	0.0005
240 SAVI	2.4379808	1.076313	2.27	0.0250
251-1	-0.188991	0.064595	-2.93	0.0040
287-1	-0.024632	0.104636	-0.24	0.8142
287 RVI	0.2558029	0.074998	3.41	0.0008
287 DVI	0.1770048	0.061714	2.87	0.0047
287 TVI	-0.003379	0.001429	-2.36	0.0194
320NDVI	-20.29549	6.111004	-3.32	0.0011
320 RVI	2.017974	1.379136	1.46	0.1456
Sum RVI	-0.05204	0.016905	-3.08	0.0025
Sum (5) TVI	0.0005286	0.000209	2.53	0.0125

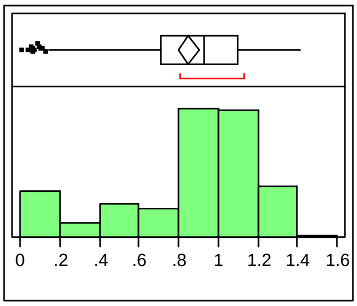
Figure 7.24: Predicted versus actual wheat crop yield, all parameters

Mean of Response	0.754663
Observations (or Sum Wgts)	160

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-0.181784	0.685979	-0.26	0.7914
181-2	0.1020706	0.039974	2.55	0.0117
221-2	0.0959419	0.046986	2.04	0.0429
221-3	0.027279	0.016116	1.69	0.0926
240-3	-0.059191	0.016057	-3.69	0.0003
251-1	-0.153656	0.077399	-1.99	0.0490
251-2	0.0001336	0.071915	0.00	0.9985
251-3	0.0188164	0.013652	1.38	0.1702
287-2	-0.180418	0.060391	-2.99	0.0033
287-3	0.1034174	0.019636	5.27	<.0001
320-2	0.3546236	0.044587	7.95	<.0001
320-3	-0.228251	0.035142	-6.50	<.0001

Figure 7.25: Predicted versus actual wheat crop yield, band 1-3 only

The bimodal distribution of the wheat data (Figure 7.21) is considered to result partially from the frost event in the wheat crop in 1998. When removing the paddocks that the farmer noted as frosted, a more unimodal distribution was found (Figure 7.26). However, frost damage often occurs very locally- sometimes only in small parts of the paddock; it is unlikely that the dataset is entirely free of frost-damage. It should be noted that in this dataset most the low yielding outliers came from the "Jews" paddock.



Mean	0.8524866
Std Dev	0.3483055
Std Err Mean	0.0283447
upper 95% Mean	0.908493
lower 95% Mean	0.7964801
N	151

Figure 7.26: Distribution of yield data excluding wheat fields that were noted as frost-damaged (see text for full explanation)

A stepwise regression selection model was also calculated for the dataset without paddocks marked as "frosted". The step history included 8 parameters in Table 7.9 and Table 7.10 for both models (all parameters and bands 1-3 only). When applying a standard least square regression model to the selected parameters, the result for the model could be improved to 0.63 (band 1-3 only, Figure 7.28) and 0.68 (all parameters, Figure 7.27) respectively.

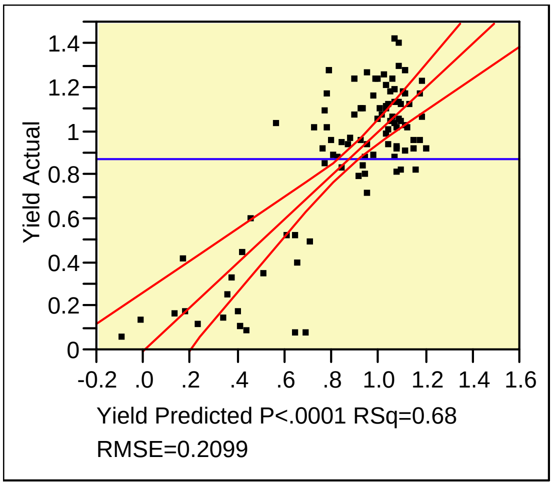
Table 7.9: Step history for multitemporal wheat yield (no frost) estimate model

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	320 RVI	0.0000	5.629759	0.4548	114.74	2
2	251NDVI	0.0000	1.158775	0.5485	80.72	3
3	320 SAVI	0.0018	0.546039	0.5926	65.748	4
4	251 RVI	0.0552	0.194445	0.6083	61.705	5
5	221-1	0.0480	0.200722	0.6245	57.466	6
6	Sum (4) Band 1	0.0011	0.512705	0.6659	43.53	7
7	181-1	0.1200	0.108962	0.6747	42.143	8
8	240-1	0.2491	0.059307	0.6795	42.3	9

Table 7.10: Step history for multitemporal wheat yield (no frost) estimate model (Band 1-3)

Step	Parameter	"Sig Prob"	Seq SS	RSquare	Cp	p
1	181-2	0.0000	3.207869	0.2592	72.376	2
2	240-1	0.0000	1.468458	0.3778	47.572	3
3	320-2	0.0024	0.717578	0.4358	36.474	4
4	320-3	0.0001	1.092352	0.5240	18.536	5
5	287-1	0.0031	0.530386	0.5669	10.854	6
6	221-1	0.0133	0.347485	0.5950	6.5117	7
7	251-1	0.0252	0.26982	0.6168	3.5867	8
8	221-3	0.0966	0.144082	0.6284	2.9567	9

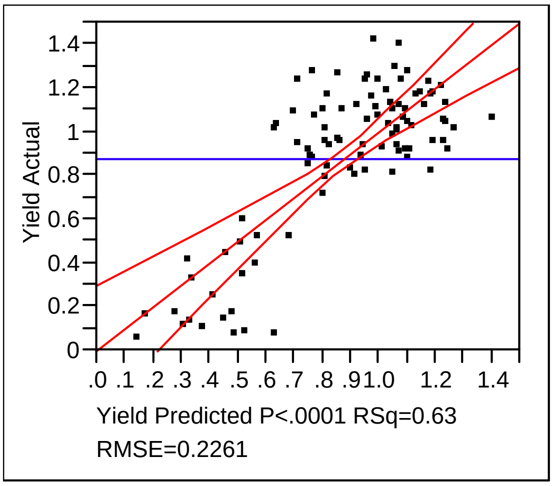
Stepwise yield model with all parameters



RSquare	0.67951
RSquare Adj	0.651022
Root Mean Square Error	0.209944
Mean of Response	0.876783
Observations (or Sum Wgts)	99

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	10.426747	2.588552	4.03	0.0001
181-1	0.0787793	0.054587	1.44	0.1524
221-1	0.2349049	0.067918	3.46	0.0008
240-1	-0.128455	0.11074	-1.16	0.2491
251NDVI	2.5328147	2.21743	1.14	0.2564
251 RVI	-0.035634	0.034766	-1.02	0.3081
320 RVI	-13.1092	3.386827	-3.87	0.0002

Stepwise yield model with SPOT Band 1-3



RSquare	0.628395
RSquare Adj	0.595364
Root Mean Square Error	0.226067
Mean of Response	0.876783
Observations (or Sum Wgts)	99

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.9387723	0.600784	3.23	0.0017
181-2	0.0532343	0.031098	1.71	0.0904
221-1	0.1729297	0.056925	3.04	0.0031
221-3	0.0194008	0.011555	1.68	0.0966
240-1	-0.225788	0.100653	-2.24	0.0273
251-1	-0.106424	0.049375	-2.16	0.0338
287-1	-0.195163	0.074907	-2.61	0.0107

320 SAVI	31.028908	9.185349	3.38	0.0011	320-2	0.2761162	0.045776	6.03	<.0001
Sum (4) Band 1	-0.100819	0.045649	-2.21	0.0297	320-3	-0.197108	0.037098	-5.31	<.0001

Figure 7.27: Predicted versus actual wheat crop yield (no frost), all parameters

Figure 7.28: Predicted versus actual wheat crop yield (no frost), band 1-3 only

An improved model of crop yield for wheat could be derived However, 1998 was a difficult year to develop yield models due to the substantial frost damage with resulting yield loses in most crops.

7.4 Discussion

Yield values from 558 areas of interest of 17 yield maps were extracted. For each crop type (other than barley) the Pearson Product Moment coefficient R was calculated for the pairwise correlation of yield and SPOT band 1-3, the vegetation indices NDVI, DVI, RVI, SAVI and TVI and accumulated sums. Furthermore standard least square regression models were formed, using satellite parameters selected by forward stepwise regression.

High values of R were found for canola in band 3 and most vegetation indices on all dates except on DOY 320 (just prior to windrowing). A linear regression model was fitted with R^2= 0.71 (Band 3) as early as DOY 221 (9/8/1998), and R^2=0.72 (band 3) on DOY 251 (8/9/1998). A forward stepwise modelling approach was applied to the canola dataset (utilizing all satellite data parameters from all dates) and an improved standard least square model utilizing 14 satellite data parameters was derived with an R^2=0.88. In a simpler model, only the three SPOT bands for all dates were used. The model still had an R^2=0.87. Chickpeas and wheat did not show strong single date correlation, however when applying the stepwise modelling approach, standard least square models of R^2=0.80 (chickpeas, from 18 parameters) and R^2=0.62 (wheat, 14 parameter) could be formed. Average chickpea yields in south east Australia are 1.3 t/ha (Robinson, 1994): In 1998 the chickpea fields under investigation had an average yield of 0.62 t/ha - mainly caused by effects of frost and *Ascochyta* blight. It is assumed that this adversely affected the yield model development. Frost damage was also present in the wheat fields. When removing the data from the wheat paddocks that were noted as having incurred frost damage, the wheat model could be improved to R^2=0.68. Lentils showed good single date correlations from DOY 240 onwards; however the dataset had only 16 sample points. A stepwise model approach resulting in a standard least square model obtained a R^2=0.86 (from 3 parameters). Due to the small dataset the robustness of the lentil model needs to be tested.

In the literature, correlation results between yield monitors and satellite images were reported to commonly be less than 0.25 (Pinter et al., 2003). Those results were partially attributed to the inaccuracies of yield monitors (Arslan and Colvin, 2002). In this study the correlations were not calculated on a pixel by pixel basis, but only the values in the centre of homogenous yield areas were used. Hence, training areas with highest yield map errors were eliminated, resulting in more accurate yield models.

Pinter et al (2003) suggested that as was found during the Large Area Crop Inventory Experiment (LACIE, MacDonald and Hall, 1980) it was likely that imagery collected several times throughout the season will improve yield predicting capabilities (at sub-paddock level). The reliability of yield estimated from satellite imagery decreased as the time before harvest increased as there was more opportunity for factors like drought, nutrient deficiency, insect infestation and disease to impact yields. This study found yield models incorporating multiple satellite images to perform better for all crop types (but lentils) than just single date models.

The models also need to be evaluated using datasets of other years. It is anticipated that the seasonal shifts between the years might create some problems. It needs to be investigated if the datasets can be adjusted to a "standard" reference year or if time series data on seasonal variation in crop yield may provide useful information for improving crop yield models.

Several agronomic models (using information such as sowing dates, meteorological data, fertilizer inputs etc) are available for crop yield forecasts in Australia (Fischer, 1979; Stapper 1984; O'Leary et al.,1985; Stephens et al., 1994; McCown et al. 1996; Hook, 1997; Stephens, 1995, 1997; Keating et al. 1997; Meinke, et al., 1998; O'Leary and Connor, 1996a, b; 1998; Probert et al., 1995, 1998; Stephens and Lyons, 1998. Advanced approaches to provide pixel scale yield estimates could be to utilize a local agronomic crop yield model and to fine tune it with observations from high-resolution satellite information of in-paddock variability.

Large area yield estimates with satellite imagery have been performed routinely since the 70’ for the stock market, world trade originations, governments, insurance companies and regional logistical operators, etc. Examples of such programs are the US Large Area Crop Inventory Experiment (LACIE, 1974), the ARS Wheat Yield Project (1976), Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS, 1980), the China Wheat Project (1983), the AG 20/20 (1999) and the European Monitoring Agriculture with Remote Sensing (MARS) project (1998) (Bauer, 1979; MacDonald and Hall, 1980; Hill et al., 1980; Willis, 1985; Wiegand et al., 1991; Wiegand et al., 1992; NASA, 1984; Hogg, 1986; Ritchie, 1981; Ritchie, 1982; Rosenberg, 1988; Reginato et al., 1988; McKellip, 2001; Pinter et al. 2003; Taylor, 1997; Genovese and Meyer-Roux, 1998; Genovese, 1998; Nègre, 2003; GMFS, 2003). These models use low spatial resolution satellite imagery acquired at high temporal resolution (for example NOOA) to observe the seasonal crop developments. Aigner (1999) estimated crop yields with NOAA-AVHRR and meteorological data in the Gooroc test site and found that crop yield predictions could be made at least as good as the farmers estimates (14.8-23.6% relative error, subject to crop type and date), but the low resolution of 1.1 km of AVHRR and difficulty in obtaining sufficient spatial accuracy posed a problem. Hence the 250 metre resolution data from MODIS on board the Terra and Aqua satellites (MODIS, 2005) should be investigated. The predictions could be refined by monthly high spatial resolution imagery to determine small scale variability of expected yields.

7.5 Conclusions

The year 1998 was a difficult year to develop yield forecast models as much of the crops in the area were damaged or in some way affected by frosts in late October; this resulted in reduced yields. The derived yield models need to be carefully tested in future research on data from other years to determine their accuracy in non-frost years. In this chapter simple linear regression models were tested to produce yield maps from satellite imagery prior to harvest. It was found that models using selected multiple satellite images throughout the season in general improved accuracies over single date and accumulated sums models. The model parameters had been selected with the statistical forward stepwise regression method. The results are summarized in Table 7.11.

Table 7.11: Overview of correlation results of yield and satellite parameters

	Single bands or accumulated sums	Stepwise regression selection, Band 1-3	Stepwise regression selection, all
Canola	0.85	0.87	0.88
Chickpeas	0.46	0.57	0.80
Lentil	0.89	0.84	0.86
Wheat (all)	0.48	0.53	0.62
Wheat (no frost)	N/A	0.63	0.68

In particular the models for canola resulted in good congruence (>0.85). Models need to be tested in other years and areas in south east Australia to determine their robustness.

Regional agronomic and low resolution satellite crop yield models are available; however the resolution of such models is insufficient for paddock management zones and variable rate technology. To build on the models in this research, further investigations are needed to combine existing yield models (using low resolution satellite image as well as agronomical models) with high resolution satellite images to produce improved yield estimates at sufficient spatial resolution for precision farming applications.

8. ALMIS crop monitoring system: early-phase testing of a prototype system

8.1 Introduction

Farmers scout their fields to pick up insect, pest and disease damage and other abnormalities. Often they climb in the roof of the tractor to get a bird's eye view of part of the paddock. As fields in south east Australia are large (115ha in average), scouting is a tedious and time consuming activity. Using satellite technology, it is possible to give farmers imagery with a bird's eye view of their paddocks. An early phase prototype of a satellite crop monitoring system for farmers (ALMIS) was tested in 1998. Vegetation Index (VI) images were derived from satellite imagery and delivered digitally and as hardcopy to 25 farmers in the Gooroc area in Victoria. This chapter describes the crop monitoring system and examines the ability of the VI images to discriminate crop health, variability in environmental conditions and treats to crop production. The author argues that delineation of problems in the field with spatial reference enables farmers to make informed management decisions and to use the information for precision farming such as variable rate technology (VRT) and management zone delineation.

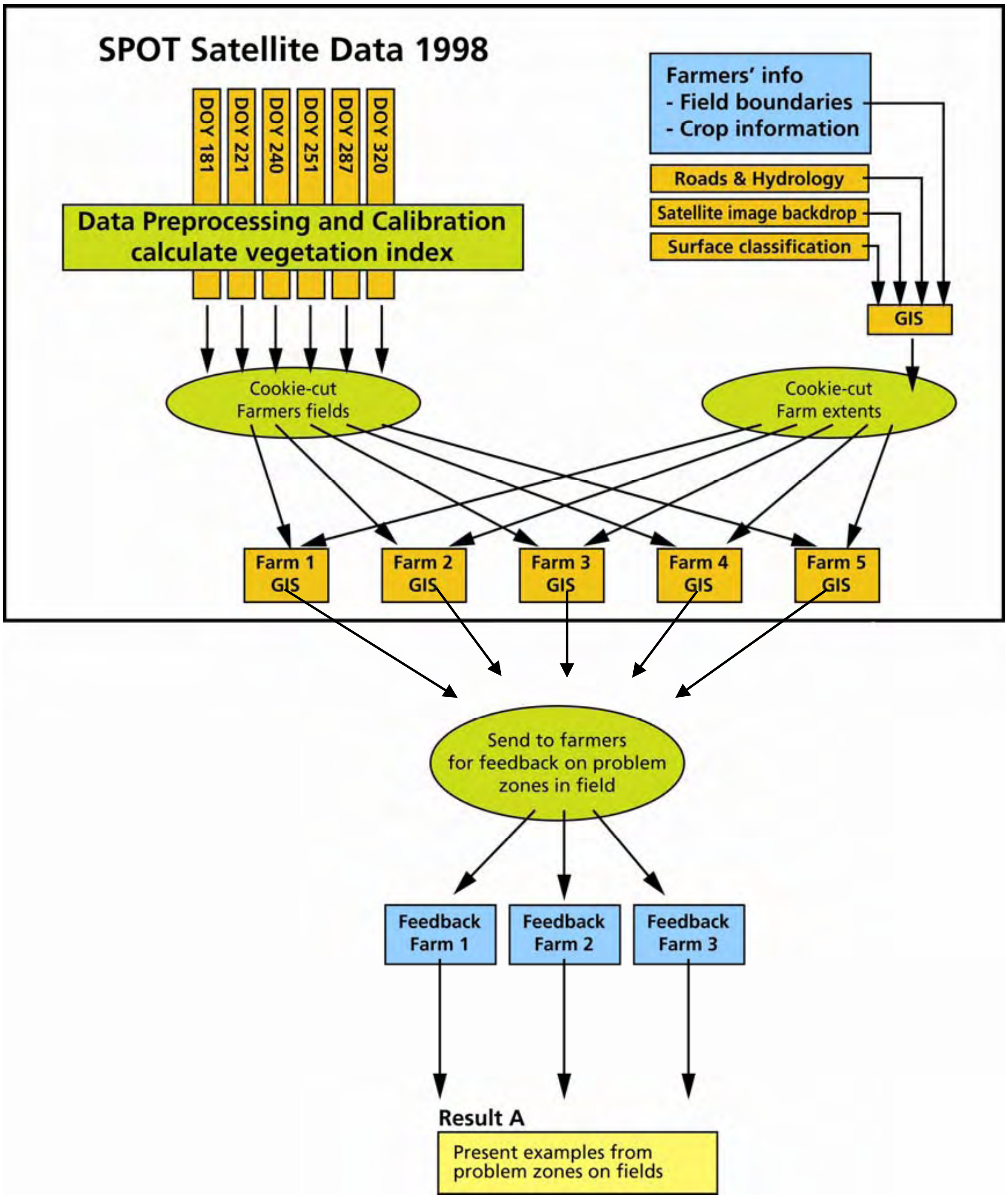


Figure 8.1: Overview of steps employed in testing of the ALMIS crop monitoring system

The flowchart gives an overview of the methods, processing steps and results discussed in this chapter. The flow chart was colour-coded. Orange represented data and databases, and blue symbolized data which were obtained by interaction with the farmers. Green circles corresponded to processing steps while yellow denoted the results. See text for full explanation.

8.2 Prototype concept

The data used in this chapter were the 1998 SPOT Satellite data as described in Chapter 4. The farmers provided information on field boundaries and crop information, as well as feedback on the ALMIS information products regarding problem fields and concerning ALMIS concept and services.

During the ALMIS project, satellite imagery was processed and a vegetation index (VI) was delivered to the participating farmers (Figure 8.1). It was anticipated to deliver four updates throughout the crop season for each farm. Due to the availability of cloud-free imagery it was possible to deliver 5 updates throughout the 1998 vegetation growth cycle. The information was made available to the participating farmers as digital information as well as semitransparent hardcopy maps. These hardcopy maps could be overlaid on a laminated satellite overview map (1:20,000 scale), which was also supplied to each farmers. From the 25 participating farmers, 17 selected electronic data (10 via e-mail, 7 via floppy disk in the mail) and 8 farmers wanted hardcopy prints because they did not have access or skill to use a computer.

8.2.1 Farm GIS "ALMIS Starter Kit "

The digital vegetation indices could be integrated in farm GIS packages for use in precision farming applications. However, only one of the ALMIS participants had access to GIS software. As GIS technology was an integral part of precision farming, ALMIS participants were offered a basic farm GIS and to attend training workshops. Furthermore the ALMIS team assisted individual farmers regarding technical questions. Ten ALMIS participants ordered a basic Farm GIS of their farm.

Several image display and GIS software as well as farm management software packages were evaluated. ARC Explorer was chosen as it was free and covered basic functions such as (ESRI, 1998):

- Satellite imagery could be visualized
- GIS layers could be displayed and queried
- Zooming
- Determination of spatial coordinates of points of interest
- Simple map printing
- Interface for use via the web
- Easy use
- Freely available

The data included in the Farm GIS consisted of the components: Image “backdrop”, paddock boundaries and information, road and hydrology vectors, and surface classification. Furthermore vegetation index images were integrated into the Farm GIS throughout the season.

Image “backdrop”

The image backdrop was a 10 metre resolution merged satellite image. It was created by combining a 10-metre pixel size panchromatic SPOT image with a 30-metre multi-spectral Landsat TM image, using the Browey algorithm (Pouncey et al., 1999). The backdrop image covered the whole farm extend, defined by a rectangle around the paddocks with the furthest north-west and south-east extend.

Paddock boundaries and information

The field boundaries and paddock information were supplied by the farmers. Figure 8.2 shows the image backdrop with the overlaid paddock boundaries for farm 14.

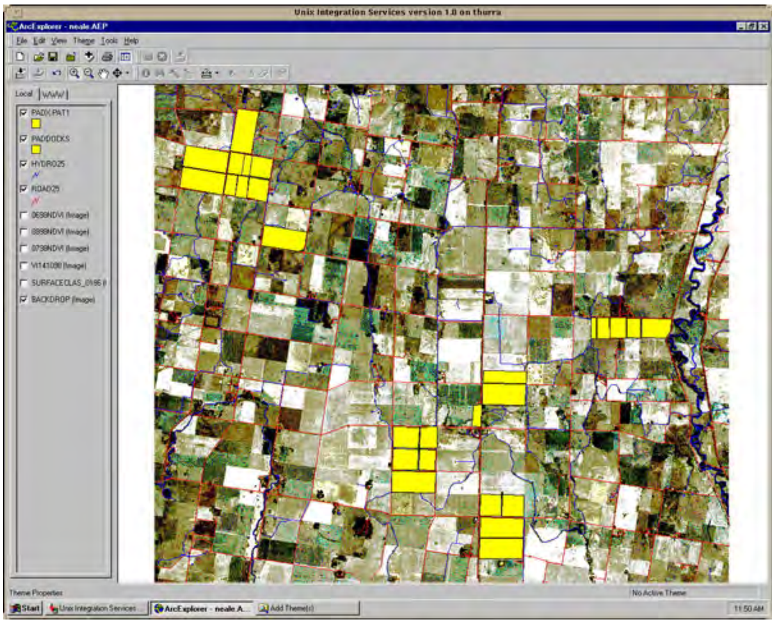


Figure 8.2: Image "backdrop" and paddock polygons displayed in yellow

Utilizing the information and query tool in Arc Explorer, farmers could retrieve the following information on previous paddock management:

- The paddock name

And paddock history for the years 1995, 1996, 1997, 1998, including:

- Crop type
- Crop variety
- Sowing date
- Seed rate
- Harvest date
- Yield results [in t/ha]
- Remarks about special crop conditions, diseases, climatic effects etc.

Roads and Hydrology

Road and hydrological data were obtained from the 1:25,000 digital corporate library of the Victorian Department of Natural Resources and Environment and cut to the farm extend (hence corresponding in size and location with the image backdrop). Roads were represented in red, hydrology colour-coded as blue lines (Figure 8.3).

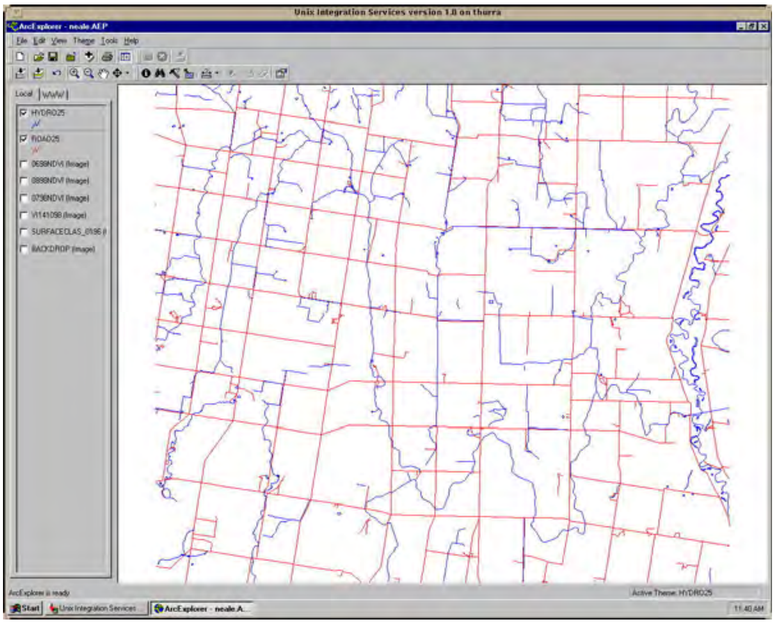
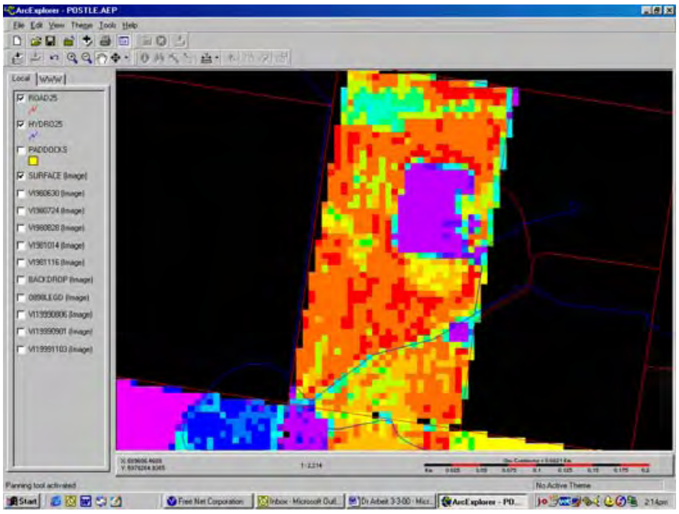


Figure 8.3: Roads and hydrology

Surface Classification

An unsupervised ISOCLAS classification (Pouncey et al., 1999) with 15 classes was conducted on a TM image, acquired in summer 1996. This classification showed the spectral differences of the surface cover on the acquisition date. Most paddocks had been harvested and the surface consisted of bare ground and bare ground with stubble. The in-paddock variability in the classifications was mostly related to differences in soil type and management practices affecting soil structure. However, also certain weeds were present (often linked to soil type). The surface maps were suitable as a guide that assisted in the selection of soil sampling locations. The Alphalane paddock of farm 14 in Figure 8.4 was given as an example for the surface classification.



The orange-red class represented the Australian soil class of vertic and calcic, mesonatric red Sodosol (Great soil group: red-brown earth). The smaller yellow patches in the paddock were verified to be sandy banks of the "Parilla Sand Formation" (tertiary period). The green class (NW corner) was located in a part of the field that received surface water run-off from Mt Jeffcot, a gneissic outcrop to the north east of the paddock, and brought fine soil particles from the neighbours' paddocks (part of quaternary fan deposits, hillwash) . The management practice of stubble retention in the paddock caught the fine soil particles contained in the run-off water. The purple colour showed a tree class.

Figure 8.4: Surface classification, Alphalane paddock

To produce an ALMIS Starter Kit the following steps were adopted:

Table 8.1: Summary of "Starter Kit" processes and tools

Identify fields on hardcopy map	Farmers
Digitize field boundaries and create vector	ERDAS Imagine Vector (ERDAS)
Attribute paddock polygons	ERDAS Imagine Vector (ERDAS)
Produce farm extent	ARC INFO AML (ESRI)
Roads & Hydro (1:25,000) for farm extent	ARC INFO AML(ESRI)
Produce Backdrop Image (VIS & PAN merge)	ERDAS Imagine (ERDAS)
Cut backdrop image for farm extent	ARC INFO AML (ESRI)
Unsupervised classification of summer TM image	ERDAS Imagine (ERDAS)
"Cookie-cut" surface classification for each field	ARC INFO AML (ESRI)
Produce hardcopy satellite overview map	ARC INFO AML (ESRI)
Burn dataset to CD and mail to farmers	

8.2.2 Crop monitoring Vegetation Index product

Data selection

SPOT routinely acquired data over Australia for the archives, but in 1998 a request was made for additional acquisition dates for the test site. The data used for the Vegetation Index (VI) images to the farmer were described in Chapter 4. The first image was acquired on the 30 June, after crop emergence. The ACRES quick- look archive was searched daily for available SPOT imagery and data quality. Cloud cover is often a problem for time-critical application during winter in Victoria. In 1998 it was on occasion difficult finding good quality data at the right time intervals. The challenge was to decide if to wait longer for a good quality, cloud-free dataset or to select data that were quite close to the last acquisition data (and by the time the decision was made has become “old data”). Overall, the data selected in 1998 were cloud-free, but some data had occasional small clouds. However, almost all fields under investigation were unaffected.

Vegetation index data processing

SPOT satellite data were checked for quality (histograms) then atmospherically corrected (Richter, 1996), geo-referenced and the NDVI (Normalized Difference Vegetation Index) calculated (see Chapter 4 for data calibration).

As ARC Explorer had difficulties displaying colour tables attached to a floating data set, the vegetation index was multiplied with the factor 100 and saved as a conventional 8-bit dataset. Furthermore negative values were set to 0 as there was no relevant crop information in those data ranges.

The result from 0 to 100 was colour-coded in rainbow colours, with purple indicating low VI values (low in green biomass) and red representing a high VI with lush green vegetation. An example paddock is shown in Figure 8.5 with a legend in Figure 8.6.

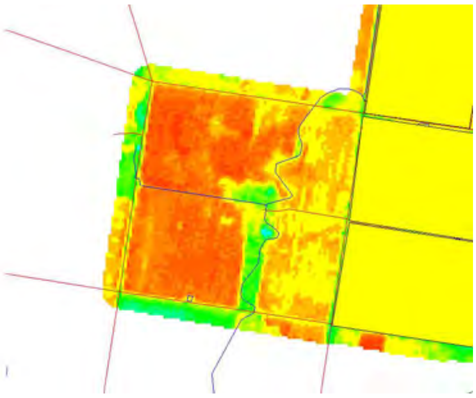


Figure 8.5: VI of Adelines paddocks, August 1998

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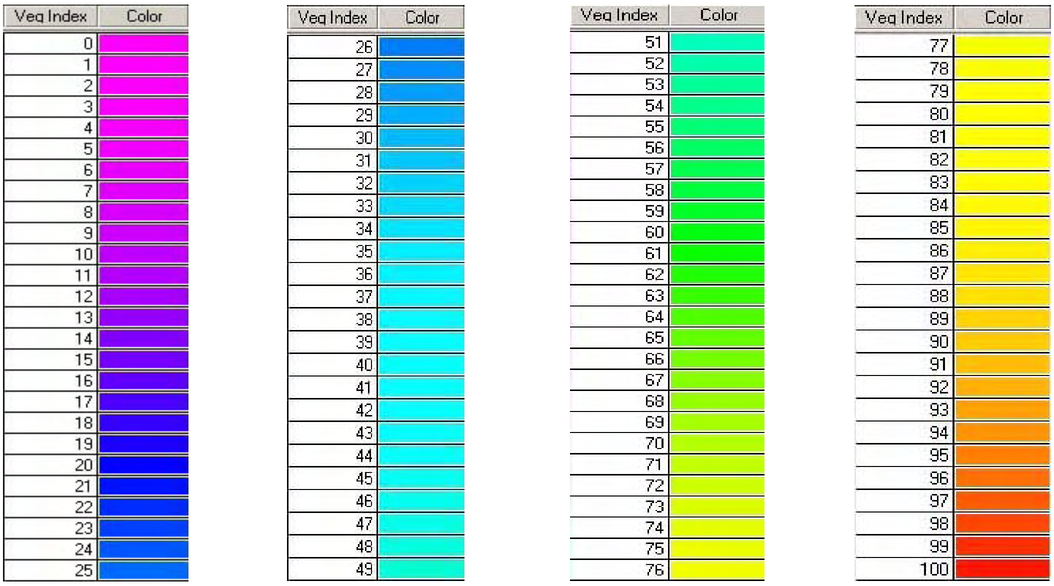


Figure 8.6: Colour-coded vegetation index legend

Data Delivery

The VI was delivered as a digital information product, a GIS raster layer that integrated into the ALMIS "Starter Kit". Alternatively, farmers could choose a bitmap or jpeg file (for viewing or integration into other farm management software). The delivery was initially via e-mail or floppy disc in the mail. However, some of the phone lines that the farmers used for their modems in 1998 were old copper cables and data transfer was very slow and unreliable. Since the farmers' email programs were set up to automatically download attachments, there was concern that a file with the VI attachment might congest their email system. Therefore a project web page with a "members only" section was created (ALMIS, 1998). Farmers were given a User ID and Password to access their data for downloading. When new satellite data were processed and available, an e-mail was sent to the participating farmers, informing them about details of the latest data acquisition. The email contained a link to the members-only web page (Figure 8.7). Farmers could then download the data at their convenience and also share their User ID and Password with farm partners and farm consultants.

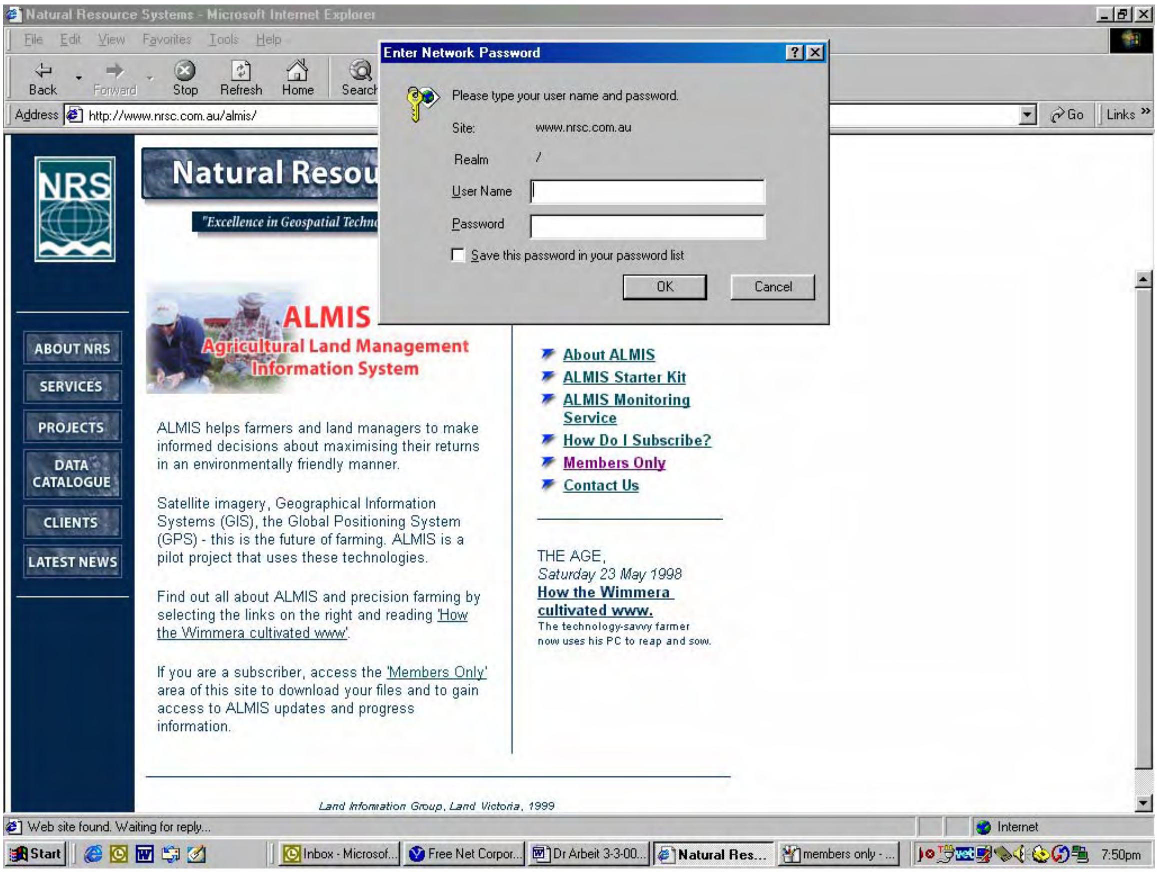


Figure 8.7: web site, "Members only" login

Farmers with no computer access were mailed hardcopy map prints at 1:20,000 scale of the VI of their paddocks. The printing and mailing of the hardcopy images to the farmers was found to be a time consuming and labour intensive process.

Delivery time

Initially in 1998, the process from satellite data reception at Alice Springs to display of the quick-look imagery in the ACRES archives (accessible through the web) took multiple days, sometimes even weeks. Once the data were selected and ordered, delivery took another length of time, often further two weeks. Then data needed to be processed, packaged and distributed to the farmers. Hence the initial delivery times of the information product to the farmer was very slow and in great need of improvement in order for the maps to become an effective working tool.

Early in the crop season, all the processing routines were done "manually" until AML programming code was written to speed up most processing routines through automation. Subsequently delivery of the digital VI product via the Internet could be accomplished within maximal two working days after data had been received from ACRES. After discussion and close cooperation with ACRES the turn-around time from reception to delivery was enhanced significantly. It was vital that the information was made available to the farmers as quickly as possible, so they could manage current problems, not just have historic records of their crop. The timely availability of the information was criticized by the farmers, but could be significantly improved by the delivery of the last trial dataset in the 1998 season (to 1.5 weeks).

Summary of Crop Monitoring processes and tools

To produce the crop monitoring vegetation product, the following processes where applied:

Table 8.2: Summary of Vegetation Index processes and tools

Data selection and ordering	ACRES web site (AUSLIG)
Data import	ERDAS Imagine (ERDAS)
Geo-rectification (SPOT Model)	ERDAS Imagine (ERDAS)
Atmospheric corrections	ATCOR (GEOSYSTEMS)
Calculate Vegetation Index	ERDAS Imagine (ERDAS)
Create legend	Freehand (MACROMEDIA,)

Cookie-cut parcels, map production, data export	ARC INFO AML (ESRI)
Electronic Delivery	
QA Test of Delivery product	ARC Explorer (ESRI)
Internet Site update; make files available for downloading	
e-mail notice of new data with link	
Mail Delivery	
copy ARC Explorer files or BMP, TIFF files and mail)	Mail Floppy
Print hardcopy maps and mail	ALCHEMY (Handmade Software)

8.3 Results

During a workshop in February 1999, the participating farmers provided feedback on ALMIS and reported on the information they gained from the VI product. The participants shared noteworthy information they had collected throughout the 1998 vegetation growth cycle about differences within their paddocks.

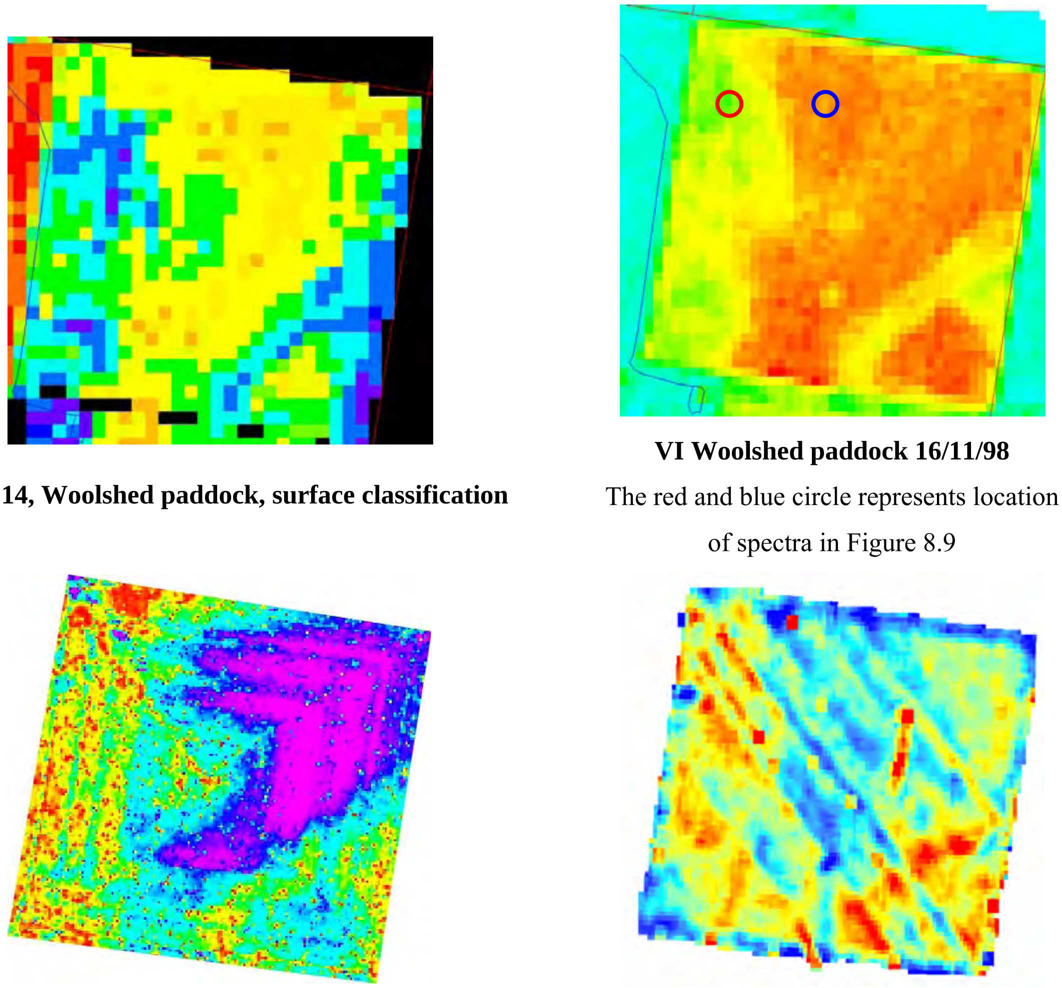
The information supplied was grouped in three categories:

- In-Paddock variability triggered by environmental factors (soil, climate) (85 observations by farmers)
- In-Paddock variability caused by insects, pests, diseases (27 observations by farmers)
- In-Paddock variability due to farm management issues (137 observations by farmers)

8.3.1 In-Paddock variability due to environmental factors

Soil type

As an example for variable crop growth and yield results due to various soil types, the Woolshed paddock of Farm 14 was presented in Figure 8.8. The pattern of the different soils was reflected in the vegetation index from November 1998, but also in the yield maps of both years, 1998 and 1996. Figure 8.9 shows the corresponding spectral properties for SPOT band 1 to 3 obtained from the various soil types, together with the baseline reference spectrum for chickpeas in November (as derived in Chapter 5).



Farm 14, Woolshed paddock, surface classification

VI Woolshed paddock 16/11/98

The red and blue circle represents location of spectra in Figure 8.9

Woolshed paddock yield map 1996

Woolshed paddock yield map 1998

Figure 8.8: Soil type variances in the Woolshed paddock as seen in satellite imagery and yield maps

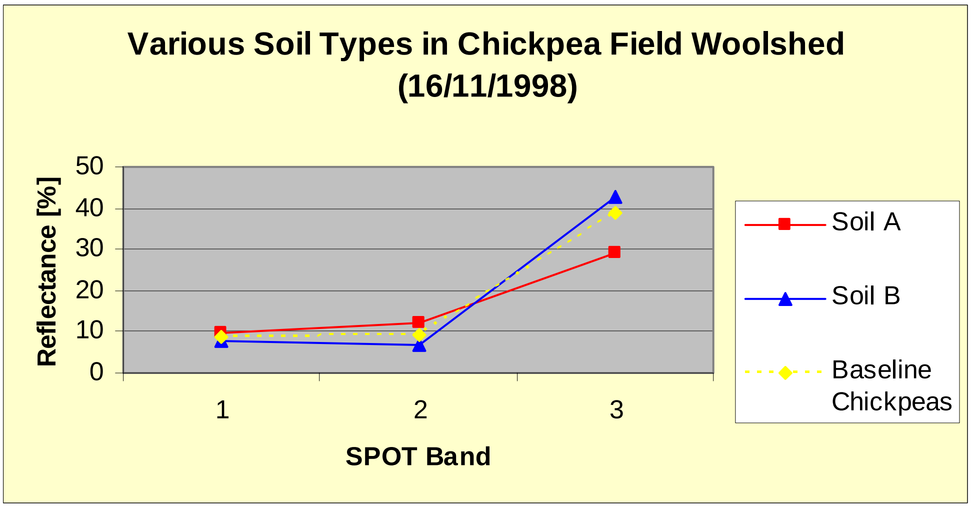


Figure 8.9 Woolshed paddock corresponding spectral properties from November 1998

Soil types in the paddock often follow the topology, hence different soil types were found on higher and lower lying regions in the paddock. As water flow is influenced by gravity, water availability also varies with topological location in the paddock. Frost damage is often found to be more severe in low laying, enclosed areas of the paddock.

Frost

The climatological definition of frost is the occurrence of an air temperature of less than 2.2°C, and a severe frost occurs when the air temperature decreases below 0°C (Thompson, 1995). This definition was used because air temperature is measured at a height of about 1.3 metres above the ground. Overnight the ground temperature may be several degrees lower than the air temperature at thermometer height. Such radiation frosts occurred when there was a rapid loss of heat by radiation from the ground surface to the air, due to the absence of cloud or moist layers in the upper atmosphere. Air in contact with the ground lost heat by conduction, so that cold air accumulated close to the ground (Thompson, 1995).

Symptoms of frost damage in grain

In grain, several symptoms of damage were observed after a frost event. According to Cole (2004) these included the following:

- Small, shrivelled grains containing material resembling polystyrene which were dispelled from the back of the header at harvest.

- Plump grains which, when squeezed, were full of water. This liquid evaporated, leaving a severely pinched grain, high in alpha amylase (capable of degrading starch), with a low falling number. When harvested, these grains were likely to be screened out due to their small size, and their poor quality lead to downgrading to 'feed wheat'. Most grains could not be used as seed for the following year due to poor germination and low vigour.

- No grains were present in the head at all.

The frost damage was related to the stage of grain development. Generally yield was reduced and grain quality adversely affected. Cereals were most sensitive to frost damage at flowering. Flowering started at the middle of the head and progressed towards the top and bottom ends of the head over the period of a few days. Frost damage could cause complete, or part, sterility of the anthers (male flower parts) resulting in empty or only partially filled grains. Damage could be identified by anthers being white and shrivelled instead of their normal light green or yellow colour (Cole, 2004). In general, the developing grain reached full volume about two weeks after flowering, and maximum grain weight was achieved about two weeks later. At this stage, the developing grain, under normal circumstances, was filled with a white milky liquid. However, grains that were affected by frost at this milk maturity stage (zadok scale 73-77) contained a grey liquid instead of the milk-like fluid, and turn white or grey with a shrivelled appearance instead of the normal plump, light green look. Depending on the severity of the frost, grain development still continued but resulted in light, shrivelled grains at maturity. In some cases plant tissues was also affected. The rachilla (stems that attach the head to stem) was weakened so that the head was easily stripped from the stem and shattered at harvest. Usually the grain had reduced germination capacity (Cole, 2004).

Symptoms of frost damage in canola

If canola seeds were killed by frost before maturity, they often remained sappy green inside, despite the seed coat maturing to the usual brown/black colour; the chlorophyll content of the seeds was "fixed" rather than developing to full maturity. As chlorophyll contaminated the canola oil, the maximum level of chlorophyll permitted was 20 mg/kg (equivalent to a maximum of 2% green seed). Chlorophyll could be removed in a very expensive process using bleaching clays (Cole, 2004).

Frost damage in 1998

The Emergency Management Australia (EMA, 2005) database reported that about 60% of Wimmera's wheat and grain crops in Victoria's north was damaged or destroyed in a 6-hour freeze on 28 October (DOY 301). Temperatures dropped to -7C. Peas, chickpeas, beans and lentils lost up to 90% of their crop, causing a damage of AUD $35 Million.

Frost damage was observed by most of the farmers participating in the 1998 ALMIS project, thus being one of the most severe reasons for yield reductions in 1998. In order to assist farmers in delineation of the areas in which the frost damage occurred, a panchromatic 10 metre resolution SPOT satellite image was acquired on the 9/11/1998 (approximately 12 days after the frost events). In Figure 8.10 the frosted area in a barley field could be delineated (marked with a red vector boundary). The corresponding spectral characteristics of the frosted (red circle) and non-frosted area (blue circle) of band 1-3 were shown. It was observed that the reflectance of the frosted barley area was lower than the non affected area in the paddock and when compared to the baseline spectral properties for barley (as described in Chapter 5).

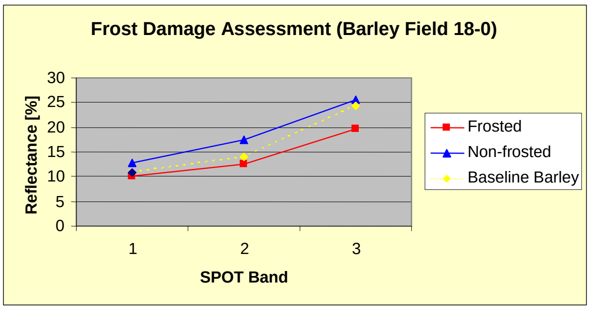
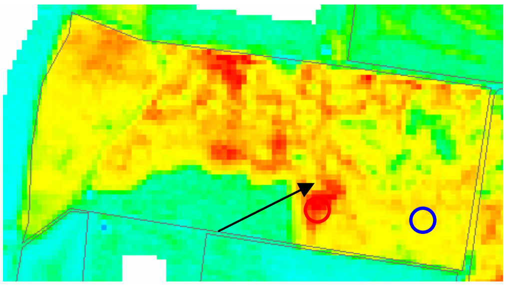


Figure 8.10: Panchromatic SPOT image delineating frosted areas in a barley paddock and corresponding spectral properties

Frosted areas in chickpea paddocks re-flowered after the frost event and hence it was found that the spectral properties were distinctive different in the near infrared band than in non-affected areas and in the chickpea baseline spectrum. Thus frosted areas could be delineated in the example paddock 3-8 (Figure 8.11).



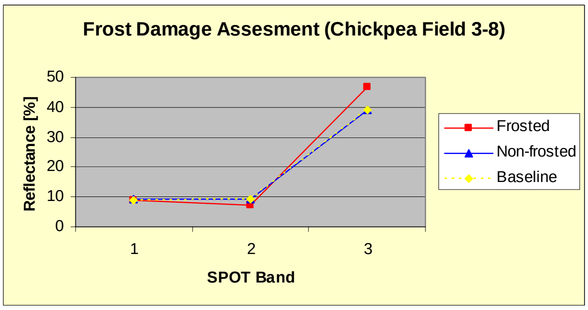


Figure 8.11 Vegetation Index image delineating frosted areas in a chickpea paddock and corresponding spectral properties

Frost damaged lentils looked substantially different in the field as well as in the spectral behaviour when compared to the non-affected areas in the field (Figure 8.12). In the near infrared band the frosted areas had substantially lower reflectance (only 20%) while the non-frosted and baseline lentil spectra had over 30% reflectance values.

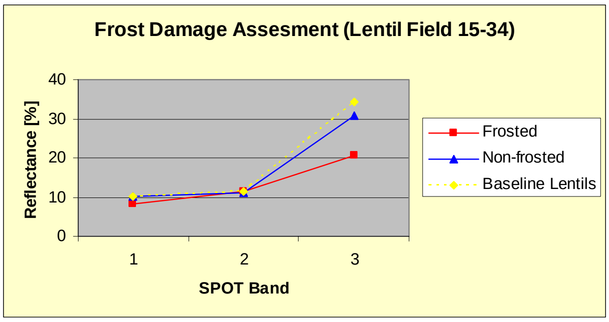
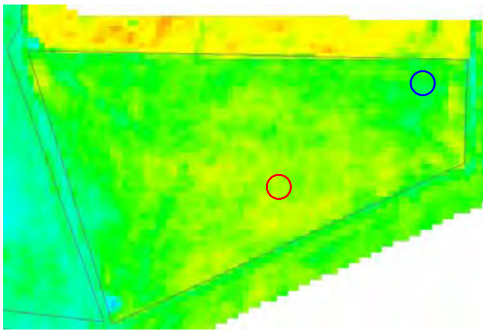


Figure 8.12 Merged panchromatic and multispectral SPOT image delineating frosted areas in a lentil paddock and corresponding spectral properties

Severely frost damaged areas in the wheat paddock 3-22 (Figure 8.13) could be delineated on the satellite imagery in the near infrared band; the reflectance values of damaged wheat was approx. 5% higher than the non damaged parts of the field and the wheat baseline spectrum. It is speculated that re-flowering occurred, similar to frosted chickpeas.



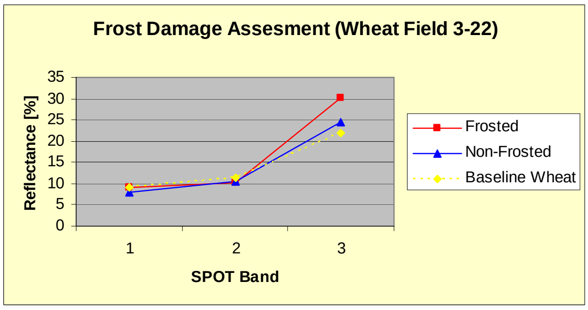


Figure 8.13 Vegetation Index image delineating frosted areas in a wheat paddock and corresponding spectral properties

8.3.2 In-Paddock variability due to insects, pests and diseases

Armyworms

There are three common species of armyworm found in southern Australia (McDonald, 1995): Common armyworm (*Mythimna convecta*), Southern armyworm (*Persectania ewingii*) and Inland armyworm (*Persectania dyscrita*).

Armyworms comprised a caterpillar pest of grass pastures and cereal crops. They were the only caterpillars that growers were likely to encounter in cereal crops, although occasionally native budworm also attacked grain when underlying weed hosts dried out. Armyworms mostly fed on leaves, but under certain circumstances were observed to also feed on the seed stem, resulting in head loss. The change in feeding habit was caused by depletion of green leaf material or crowding. In the unusual event of extreme food depletion and crowding, they have been seen "marching" out of crops and pastures in search of food, hence the name "armyworm" (McDonald, 1995).

Armyworms grew from about 2 to 40 mm in length. Caterpillars of the three species were similar in appearance and had four abdominal prolegs. They had no obvious hairs, were smooth to touch and curled up when disturbed. Armyworms could be distinguished from other caterpillar pests that may be found in the same place by three pale stripes running the length and sides of the body; these stayed constant no matter what variation in the colour of the body (Figure 8.14).

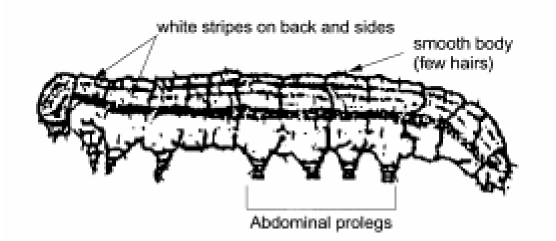


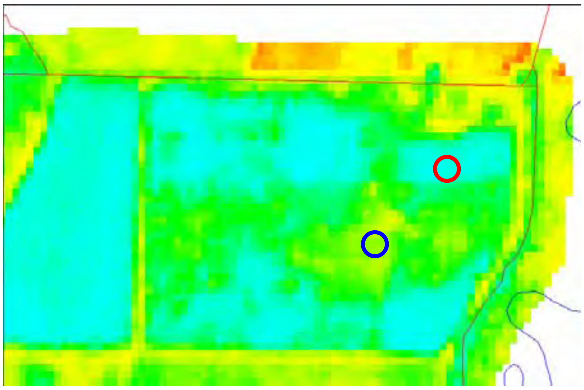
Figure 8.14 Sketch of armyworm (from McDonald, 1995)

There were six stages of caterpillar growth of which the older and larger larvae caused all the damage to crops. The larvae remained at this voracious stage only for several weeks; they soon commenced tunnelling into the soil to pupate. The mature caterpillars pupated on the surface of the soil at the base of the plant. The adult moth finally emerged at least 4 to 6 weeks (possibly many more) after pupation, and migrated away from the region. It was most unusual for crops to be reinvaded twice in succession; a heavy infestation in one year rarely resulted in a further problem in the following season (McDonald, 1995).

The crops affected included all *Gramineae* crops in particular cereals, grassy pastures, corn and maize. The young larvae fed initially from the leaf surface of pasture grasses and cereals. The young larvae (up to 8 mm) caused very little damage, and were more difficult to detect. As the winter and spring progressed and the larvae grew, they chewed 'scallop' marks from the leaf edges. This became increasingly evident by mid to late winter. By the end of winter or early spring, the larvae reached full growth and maximum food consumption. Most farmers failed to detect Armyworms until the larvae were almost fully grown and 10-20% damage resulted (in some cases complete leaves and tillers were consumed or removed from the plant). Armyworms could be eradicated with a number of chemicals (McDonald, 1995).

Example for armyworm damage in 1998

The Merrillees paddock was sown to Barley on 19/06/1998. Crop emergence took place as expected. From early on certain parts of the paddock showed less crop vitality than others. The vegetation index image from 28/8/98 clearly showed the full spatial extend of the problem (Figure 8.15). The lower vegetation index values (blue colour) indicated less biomass, due to armyworm damage. It was too late in the season to manage the problem and reseed the crop, thus farmer 14 decided to spray the paddock with “Round-up” to kill the remainder of the crop; an existing weed problem in the paddock was addressed by fallow and soil moisture preserved for the next year.



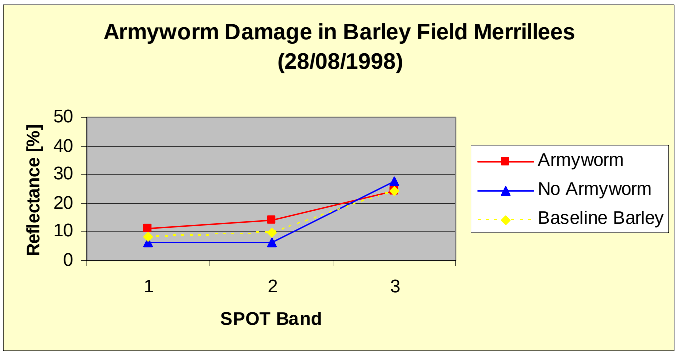


Figure 8.15 Vegetation Index image (28/8/1998) showing armyworm damaged areas in the Merrillees barley paddock and corresponding spectral properties

Wireworms

Grey false wireworm (*Isopteron punctatissimus*) is a beetle (Family: *Tenebrionidae*) native to Australia. Its spread was reported in New South Wales, Queensland, Victoria and South Australia (Rohitha and McDonald, 2003). It has become an important soil dwelling pest of canola particularly on fine textured soils, for example cracking clay. Grey false wireworm larvae did not damage cereal or pulse crops, but they had a particular affinity for canola. As canola seeds germinated, the larvae fed on the hypocotyl and the root system of the canola seedlings. With their strong mouthparts, larvae ring-barked or severed the stems and roots of the emerging or newly established seedlings. In heavy infestations, major establishment failures in canola were observed. The damage appeared as large bare patches in the paddock 3-4 weeks after sowing. Damage to seedling roots early in the season also caused forked or damaged root systems in mature canola plants, which interfered with the water absorption and plant anchorage. Bare patches required re-seeding, subject to the size of the area affected. Bare patches not only caused yield losses but they also provided havens for troublesome weeds (Rohitha and McDonald, 2003).

Figure 8.16: Photograph of wireworm (from Rohitha and McDonald, 2003)

The grey false wireworm larva grew to about 10 mm long and 1.5 mm wide with a robust black-brown exo-skeleton (Figure 8.16). It had a characteristic pair of black, up-turned spines on the last segment and powerful mouthparts. During pupation, the grey false wireworm larva turned into a pure white pupa (8 mm long and 3 mm wide) with no pupal cocoon. The pupae turned brown when they were about to moult into adults. Newly emerged adults were light brown in colour and changed into dark chocolate brown within a day. Adult grey false wireworms were 8 mm long and 2 mm wide (Rohitha and McDonald, 2003).

Grey false wireworm had a one-year life cycle. Adult females laid eggs in late summer and early autumn. In Victoria, eggs hatched around February-March, and the emerged larvae immediately started feeding on decaying organic matter in the top 10 mm of soil, depending on the soil moisture status. In dry periods, the larvae survived by moving down the soil profile. In March the larvae were about 3 mm in length. At the sowing time in May, grey false wireworm larvae had usually grown to 5-8 mm in length and were able to cause damage to the emerging canola seedlings. The larvae were fully grown by early September and pupation took place in mid September. Pupae occurred close to the soil surface and were highly vulnerable to mechanical damage at this time. Pupae did not feed and they moved by wiggling through soil if disturbed. Adult beetles emerged in October and November and found shelter under debris and in soil cracks during the day (Rohitha and McDonald, 2003).
The infestations were observed to re-occur in the same region and paddocks; therefore a determined approach over several years such as an integrated pest management was needed to minimize the adult population. Management tactics included the removal of stubble and hence shelters for adult beetles, the monitoring the larval density before sowing, the use of insecticide seed dressings or cautious use of soil insecticides, careful soil compaction after sowing and the use of a higher seeding rate. Combination of more than one management technique gave best results in reducing damage to canola crops (Rohitha and McDonald, 2003).

Wireworm damage occurred in the Hoyes North paddock of farm 14. Figure 8.17 shows the vegetation index image and corresponding spectrum. The area in the red circle corresponds to the photograph in Figure 8.18. The area in the blue circle was performing above average, with a near infrared band reflectance of 60%.

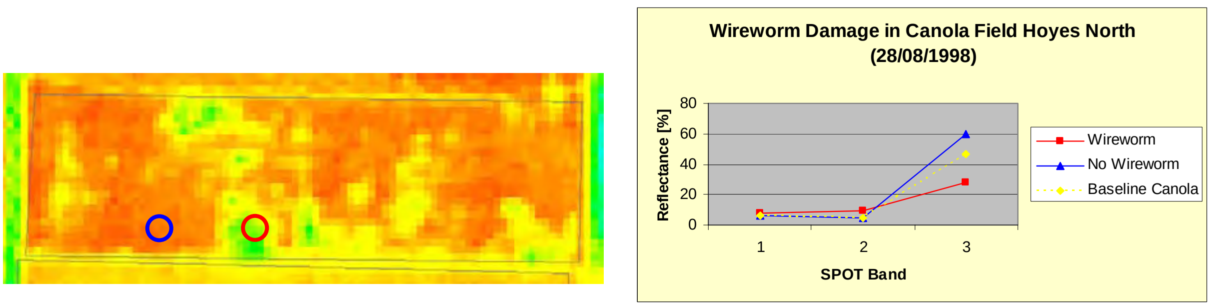


Figure 8.17: Vegetation Index image from 28/8/1998 showing wireworm damaged areas in a canola paddock and corresponding spectral properties

Figure 8.18 Photograph of the Hoyes North canola field, 25/08/98

Ascochyta blight

Ascochyta blight of chickpeas was caused by the fungal pathogen *Ascochyta rabiei*. In 1998 there was a serious outbreak of the disease in Victoria, South Australia and New South Wales, which destroyed many crops. Since then the area sown to chickpeas has been greatly reduced, as all available commercial varieties were susceptible to the disease. In order to successfully grow most of the current varieties, foliar fungicides needed to be applied throughout the growing season. Crops grown without fungicide applications were likely to suffer serious yield losses (Bretag et al., 2005).

This disease was usually first noticed in late winter when small patches of blighted plants appeared throughout the paddock. The disease spreads during cool, wet weather from infected plants to surrounding plants mainly by rain splash of spores. This created large blighted patches within the crops (Bretag et al., 2005).

Where seed was the source of infection, hot spots occurred within the paddock. Initially *Ascochyta* blight appeared on the younger leaves as small water-soaked pale spots. These spots rapidly enlarged, under favourable cool and wet conditions, joining with other spots on the leaves and blighting the leaves and buds. Small black spots (*pycnidia*), less than 1 mm in diameter, were seen in the affected areas (see Figure 8.19) (Bretag et al., 2005).

Figure 8.19. Typical symptoms of leaf and stem infection (from Bretag et al., 2005)

Figure 8.20. Symptoms of pod infection (from Bretag et al., 2005)

In severe cases of infection sudden drying of the entire plant has been observed. Elongated lesions often formed and girdled the stem, thus dying or breaking off. In some cases regrowth occurred from the broken stem. Affected areas on the pods tended to be round, sunken, with pale centres and dark margins. The fungus could also penetrate the pod and infect the seed (Figure 8.20) (Bretag et al., 2005).

The successful management of *Ascochyta* blight of chickpeas required a combination of factors. It was essential to use *Ascochyta* blight free seed which was treated with a seed dressing registered for control of *Ascochyta* blight. Seeds needed to be planted on a paddock at least 500 metres from previous year's chickpea crop. Furthermore careful use of farm hygiene (disinfection of machinery, vehicles and boots that were in contact with an infected crop), use of less susceptible varieties, crop monitoring and use of fungicides (commonly the first fungicide spray needed to be applied 4-6 weeks after sowing). The moderately susceptible varieties, such as Howzat, required spraying every 2-3 weeks. Very susceptible varieties such as Kaniva, Bumper, Sona, Tyson and Jimbour required spraying at least every 2 weeks throughout the growing season (Bretag et al., 2005).

In 1998 most of the chickpea paddocks participating in the ALMIS project were to some degree adversely affected by *Ascochyta* blight, several suffered substantial yield loss.

Figure 8.23 shows an example of the chickpea field 3-9 and the vegetation index image from October and November. In October the south east corner of the paddock had a lower (colour coded green) vegetation index than the remainder of the paddock (colour coded yellow/ orange); this was due to *Ascochyta* blight. In the November vegetation image the disease had spread and the difference between healthy chickpea plants and blight affected plants had become more substantial.

Figure 8.21: Photograph of damaged chickpea field 3-9

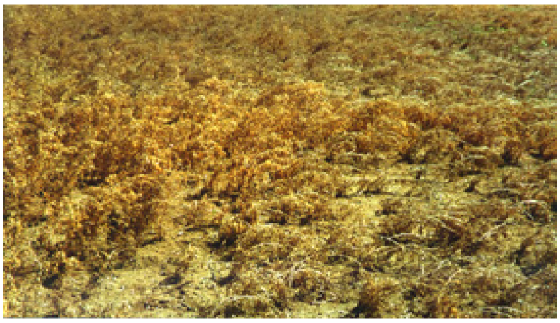
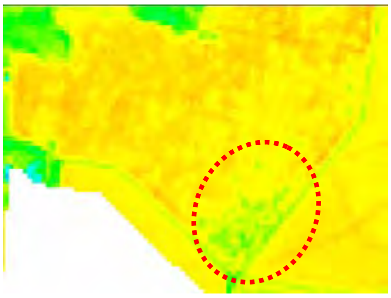
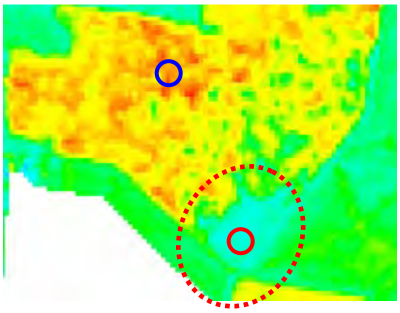


Figure 8.22: Photograph of *Ascochyta* blight damage in chickpea plants in field 3-9

Furthermore the same chickpea field is depicted in a merged panchromatic and multispectral SPOT image (November 1998), with a spatial resolution of 10 meters. Details of the *Ascochyta* blight hot spots can be seen much more clearly than in the 20 metre resolution data. Red symbolizes thriving vegetation, while grey represents areas with plants strongly affected by *Ascochyta* blight.



VI 14/10/98



VI 16/11/98

SPOT XS & PAN merged image 11/98

Figure 8.23: *Ascochyta* blight in chickpea field 3-9

An analysis of the spectra from the SPOT data from 16/11/1998 is shown in Figure 8.24. The red spectrum was derived from the area in the red circle, a part of the paddock with substantial *Ascochyta* blight damage; scarcely any photosynthetic activity was recorded in this spectrum. The blue spectrum represented thriving chickpea plants. The yellow spectrum denoted the chickpea baseline spectral properties (as presented in Chapter 5).

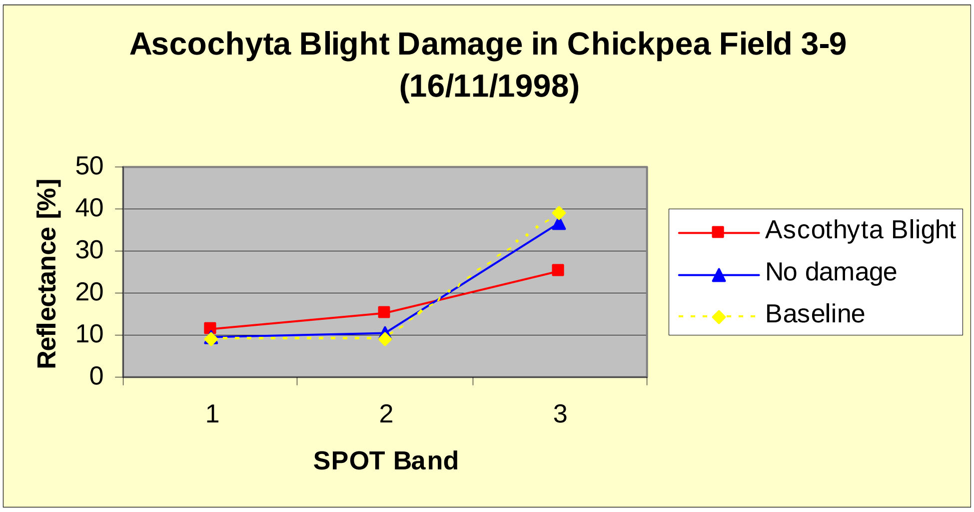


Figure 8.24 Spectral properties of *Ascochyta* blight affected chickpea field 3-9

8.3.3 In-Paddock variability due to farm management practices

Variable crop development within paddocks was in some cases caused by human intervention in the field. The majority of the observations reported by the farmers were part of this category. Often historic management decisions could still be seen in the satellite imagery. Examples found in the Gooroc area were old fence lines (Figure 8.25), areas where trees were removed (still visible after 30 years, Figure 8.26), filled-in dams and water holes (Figure 8.27, 8.28), old water channels (Figure 8.29, 8.30), soil compaction from agricultural vehicle traffic (Figure 8.31), headlands (Figure 8.32), different soil type due to mechanical soil shifting and levelling efforts (Figure 8.33), old fire scars (Figure 8.34), etc. However, most of the time there was no possibility to rectify the situation and hence the observations were a historic record rather than giving the opportunity to improve yields though active management in the given particular crop season. The information gained is nevertheless valuable information, in particular for devising crop management zones within a specific paddock.

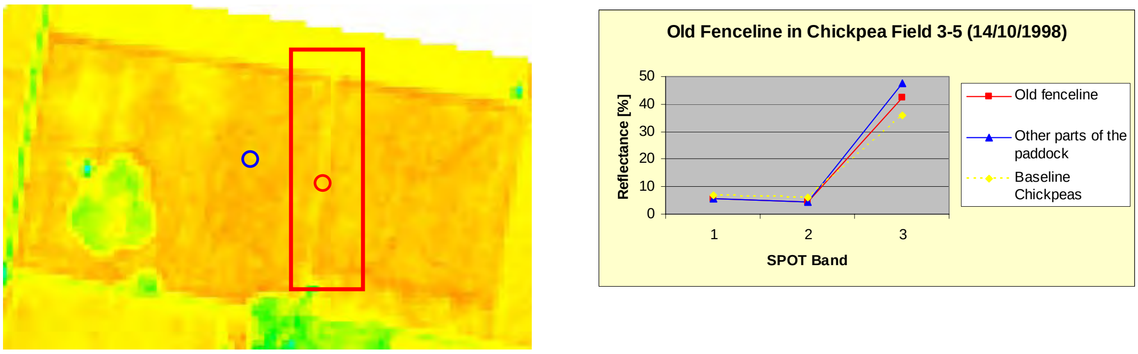


Figure 8.25: Old fence line in paddock 3-5 from 14/10/1998 with corresponding spectrum

Figure 8.26: Old tree site (removed) on paddock 18-0 from 14/10/1998 with corresponding spectrum

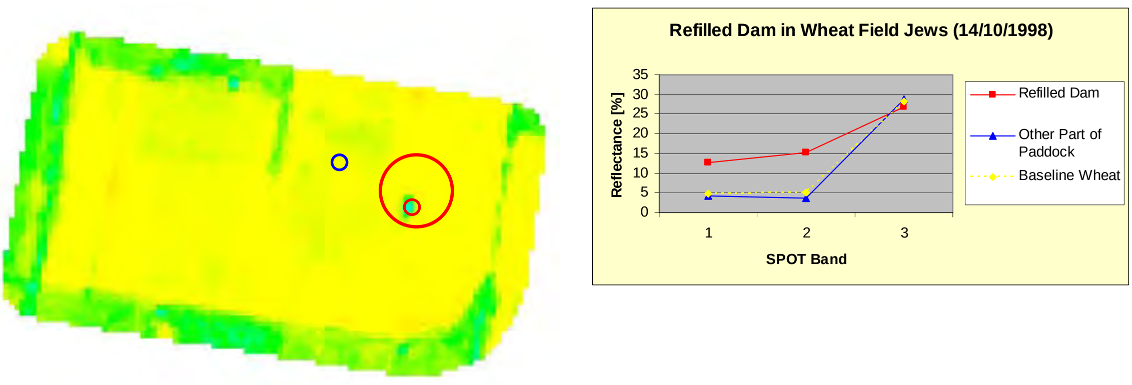


Figure 8.27: Refilled dam on Jews paddock from 14/10/1998 with corresponding spectrum

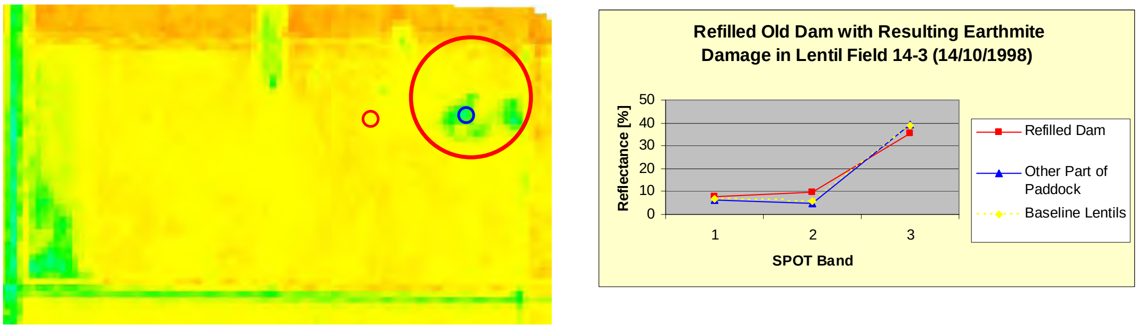


Figure 8.28: Refilled dam (with resulting earthmite damage) on paddock 14-3 from 14/10/1998 with corresponding spectrum

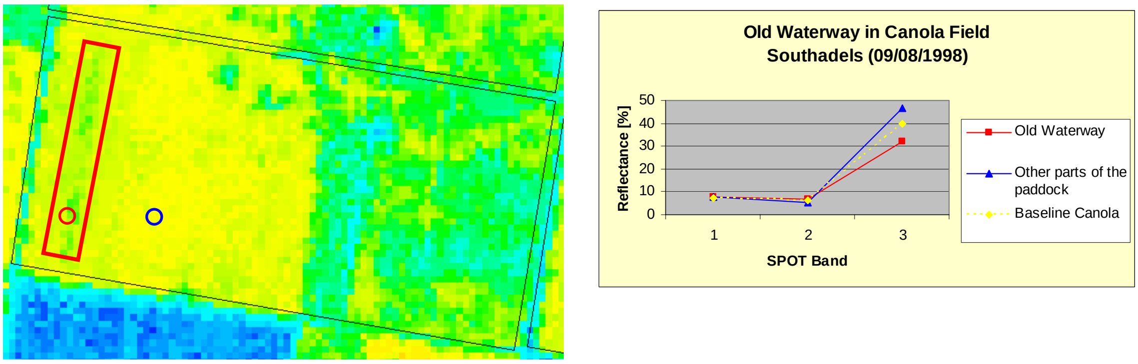


Figure 8.29: Old waterway in Adelines South paddock from 09/08/1998 with corresponding spectrum

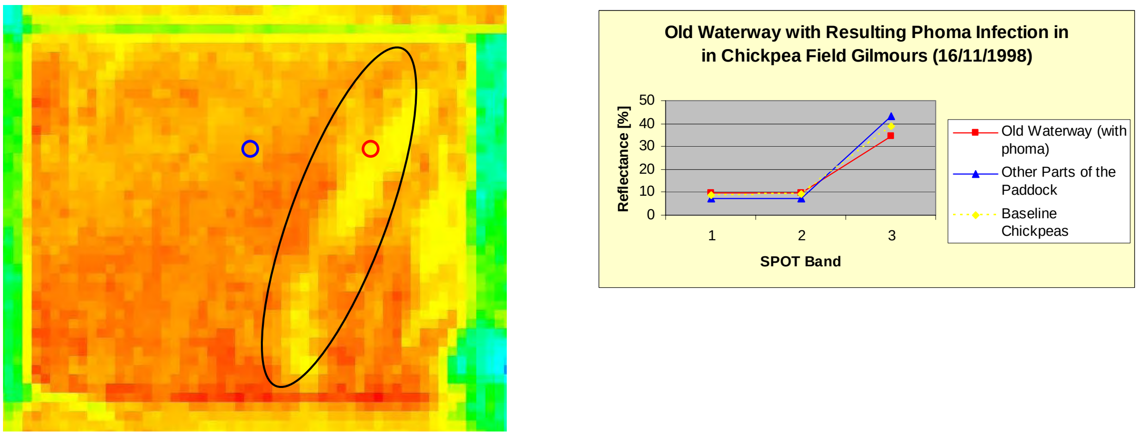


Figure 8.30: Old water way (with resulting phoma damage) in Gilmours paddock from 16/11/1998 with corresponding spectrum

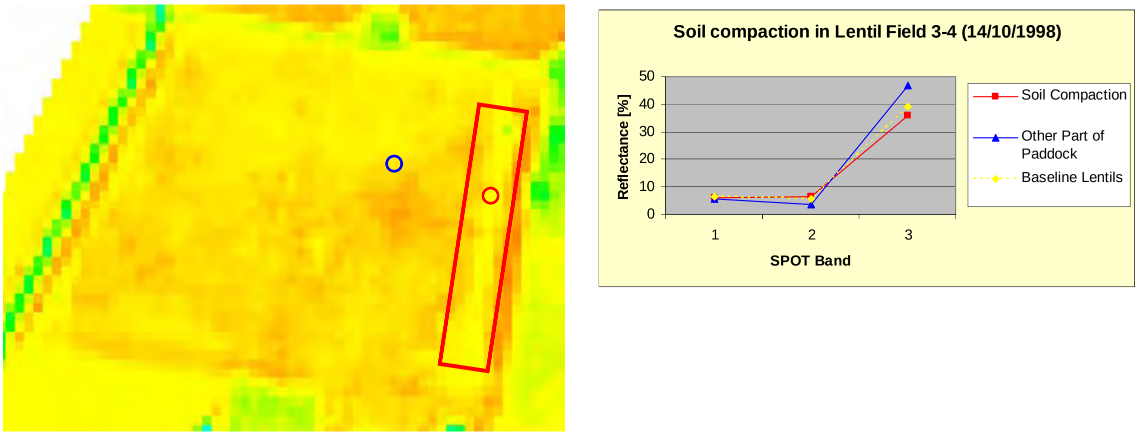


Figure 8.31: Soil compaction due to tractor path in paddock 3-4 from 14/10/1998 with corresponding spectrum

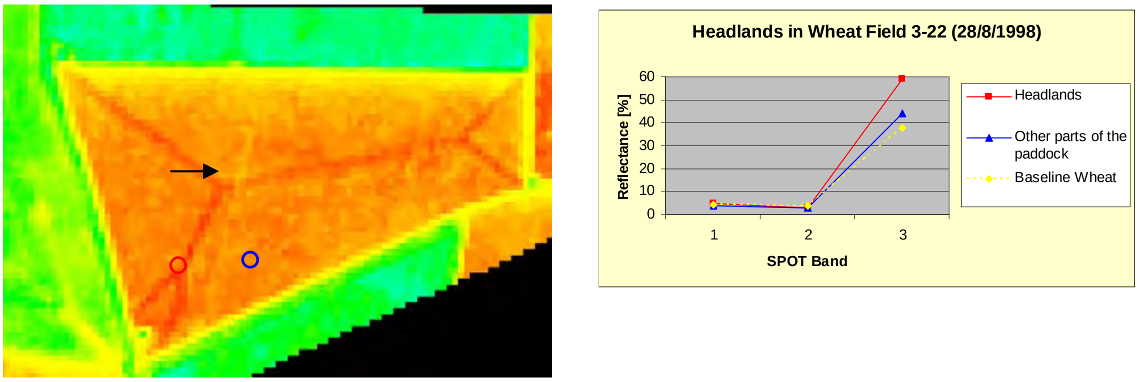


Figure 8.32: Headlands in paddock 3-22 from 28/8/1998 with corresponding spectrum

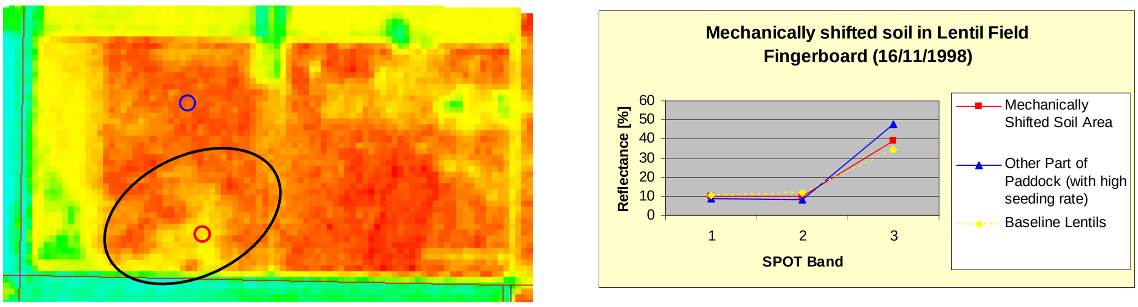


Figure 8.33: Mechanical soil shifting and levelling in Fingerboard paddock from 16/11/1998 with corresponding spectrum

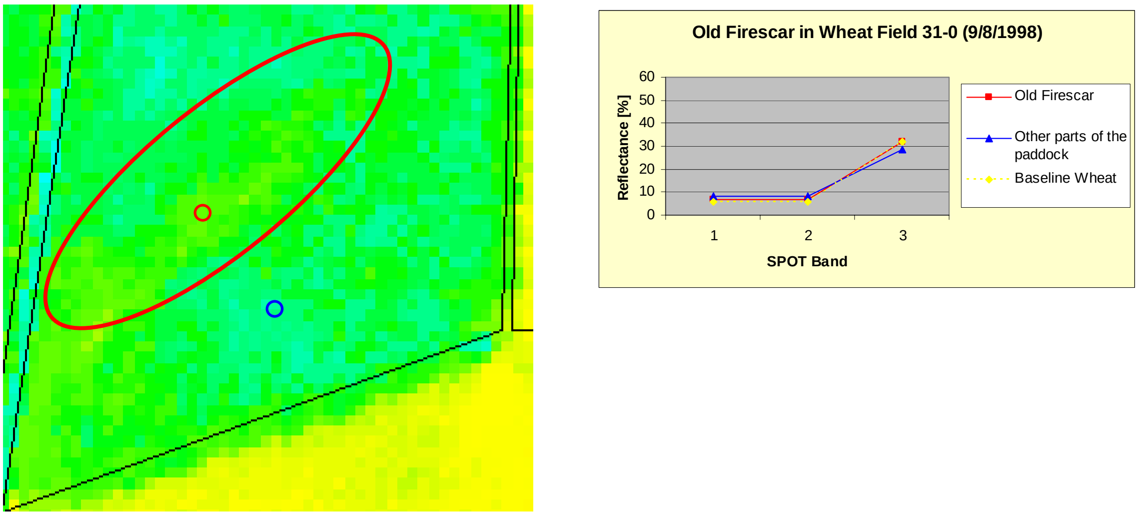
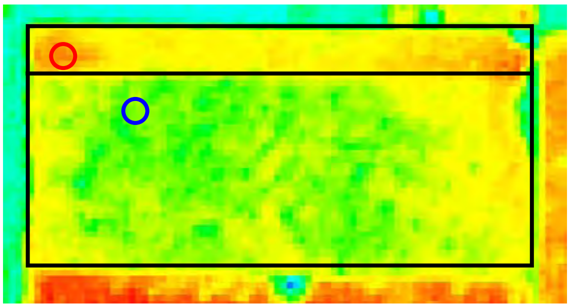


Figure 8.34: Fire scar from burnt stubble in previous year on paddock 31-0 from 9/8/1998 with corresponding spectrum

Furthermore farmer's experiments, human error and equipment failure caused distinctive patterns in the satellite imagery. It could be observed in examples such as seeder failure, double sowing, different seeding rate, multiple crop types and varieties on one paddock (in particular trial patches), spray damage due to over-spraying and blocked equipment causing uneven distribution of fertilizers and other chemicals.

Different crop variety on one paddock

Farmer 10 selected multiple varieties of chickpeas on paddock 10-1 (Figure 8.35). The northern (top) part of the paddock was sown to chickpeas of the Amethyst variety, the southern part to Lasseter. The chickpea disease *Ascochyta* blight caused severe damage to the Lassete variety and the crop died. The Amethyst variety was successfully harvested. The blue spectrum shows the *Ascochyta* blight damaged Lasseter variety, while the red spectrum illustrates the Amethyst variety which performed well on paddock 10-1 in 1998. Marked in yellow was the corresponding chickpea baseline spectrum.



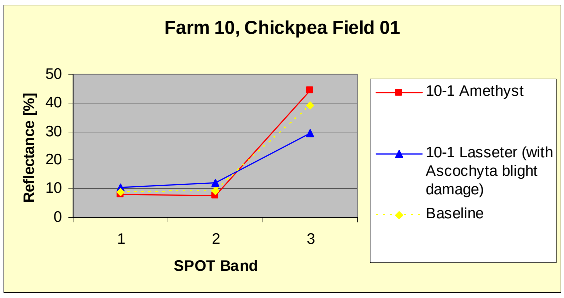
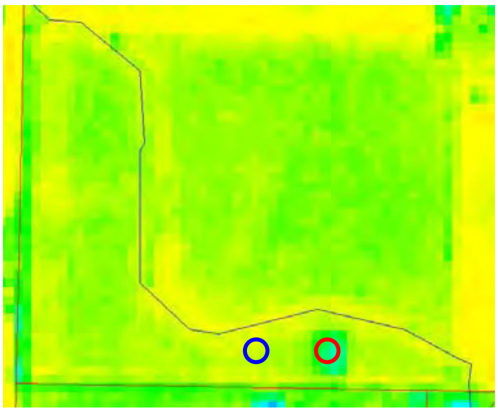


Figure 8.35: Multiple chickpea varieties and blight damage on paddock 10-1 as seen in the VI image from 16/11/98 with corresponding spectrum

Sowing errors

Figure 8.36 shows the Hills chickpea paddock on the 14/10/1998. The red spectrum was derived from the red circle on the location where the seed box was located and no sowing occurred; hence not much vegetation was present on this location. The blue spectrum was derived from another part of the same paddock where good establishment of the chickpea crop took place. The yellow spectrum denoted the chickpea baseline reference spectrum. The spectrum of the area with where the seeding error occurred had not the typical vegetation characteristics of chickpeas as did the remainder of the paddock. The area could be delineated by the satellite data.



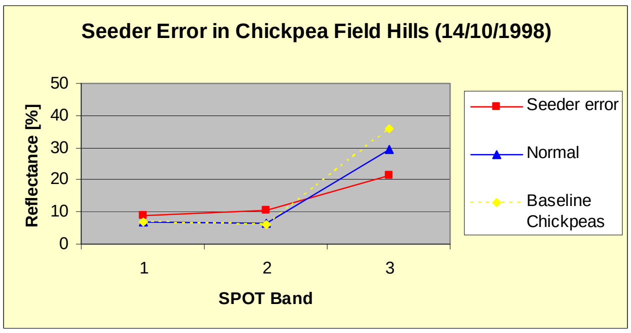


Figure 8.36: Air seed box miss in Hills paddock as seen in the VI image from 14/10/98 with corresponding spectrum

Seed rate

Farmer 14 conducted an experiment on the Fingerboard paddock (lentils) by applying different seeding rates (Figure 8.37); a 160 metres wide strip on the western side of the paddock was sewn at a rate of 25kg seed per hectare, while twice as much seed was applied to the remainder of the paddock (50kg/ ha). Different spectral signatures and hence vegetation indices could be observed in November in the respective areas. The red absorption was stronger in the area with the higher seeding rate, as was in particular the near infrared reflection (about 10% higher); in the south west corner the lentil crop experienced substantial damage caused by aphids (circled in turquoise) and retarded plant growth could be observed due to a different soil type compared to the rest of the paddock (purple circle); the change in soil type was caused when the farmer shifted soil to the area in the purple circle in order to level the soil.

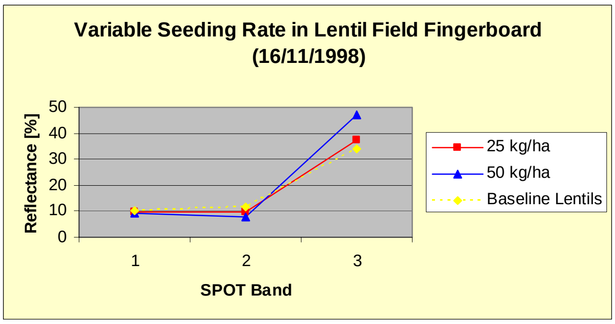
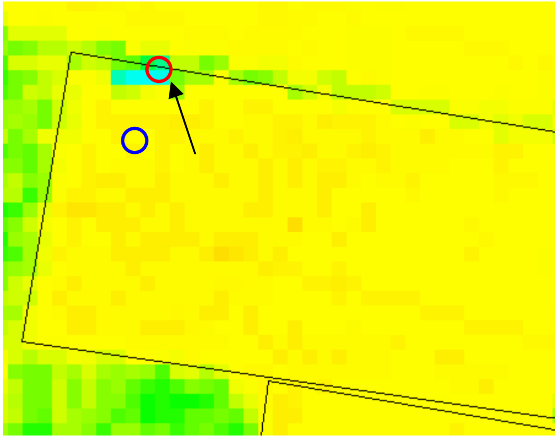


Figure 8.37: Different seeding rates in Fingerboard paddock as seen in VI image from 16/11/98 with corresponding spectrum

Spray damage

Farmer 2 noted spray damage in paddock 2-0, resulting in a bare patch in the crop (Figure 8.38).



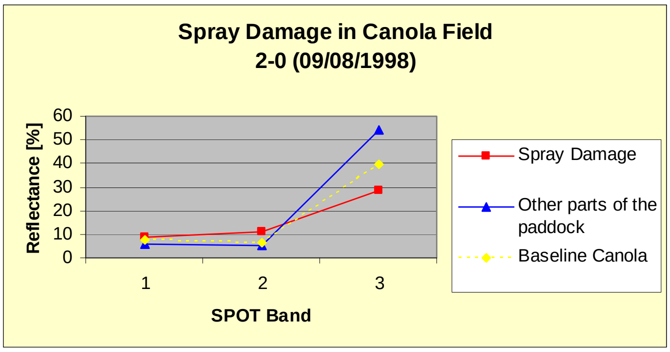
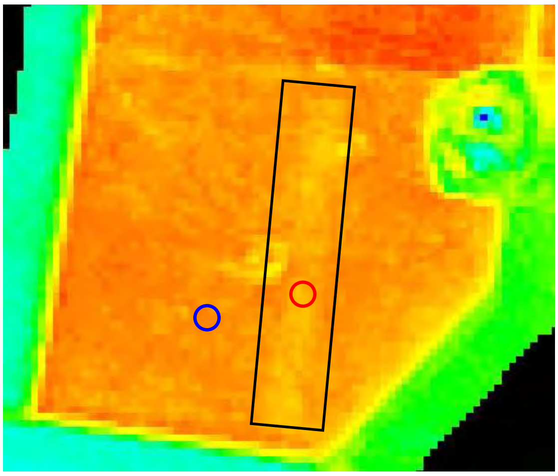


Figure 8.38: Spray damage; Farm 2, 24/7/1998 with corresponding spectrum

Various rates of fertilizer

Farmer 6 applied various rates of Urea to paddock 6-23 (Figure 8.39); the high nitrogen application rate in most of the paddock showed clearly in contrast to the marked lower rate in the middle of the field in the vegetation index image and spectrum from 28/8/1998.



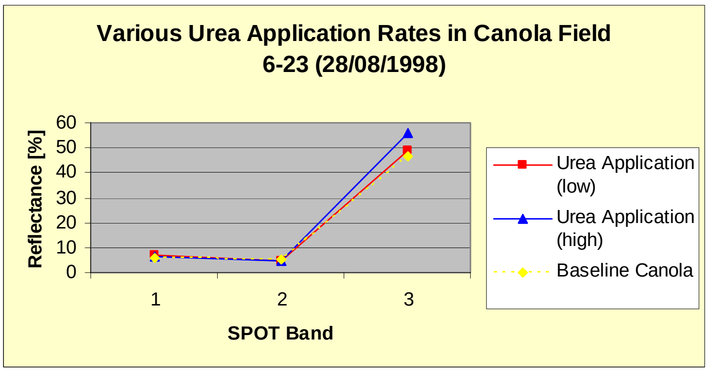


Figure 8.39: Urea (Nitrogen) application variation; Farm 6, 28/8/1998 with corresponding spectrum

8.4 Discussion

This chapter presented the ALMIS trial in which a crop monitoring system utilizing GIS and remote sensing technology was introduced to a local farming community. The early-phase prototype crop monitoring system ALMIS was tested by 25 farmers in the Gooroc area. Farmers were supplied with simple GIS software together with a dataset specific to their farm extent. The data included: 1:25,000 roads and hydrology, a merged 10 metre resolution image backdrop, a surface classification of their paddocks (which was related to soil type if the soil was exposed at the time of data acquisition), and an attributed vector layer of the field boundaries, containing information on paddock history. Throughout the 1998 crop season five vegetation index images (based on NDVI) of the paddocks were delivered in most cases electronically, and as hardcopy maps in the mail. Farmers initially found it difficult to interpret the vegetation index images; therefore training courses were conducted to familiarize the farmers with the basic principles of remote sensing underpinning the technology. When the phenomena observed in the imagery were discussed with the farmers, they understood the dynamic and could interpret the vegetation indices appropriately. Based on the vegetation index images corresponding field observations were noted by the farmers throughout the season.

A multitude of reasons were presented which affected the spectral signature of the remote sensing data, and thus allowed delineation of specific areas. In most cases it was not possible to give a specific reason for the variance from only the SPOT data; however the vegetation index maps were a most useful tool for the farmers' scout walks.

With the information gained from the crop monitoring system prototype farmers were able to take guided scout walks, determine the reason for crop variability and after assessment of the spatial extend of the observed problem changed their management techniques. For instance, one farmer had an armyworm infestation of his barley crop. He was aware of the infestation, but the vegetation index image showed him the exact extend of the problem. Instead of eradicating the Armyworms and fostering a reduced area of crop to maturity, he recognized that the more viable approach was to kill the crop and manage the paddock for a weed problem and preserve soil moisture for the following year. A further example was that a farmer could see the exact extent of the *Ascochyta* blight fungal disease in his chickpea field. He realized that the cost of harvesting the non-affected crop was higher than not harvesting the whole paddock. In another example a farmer could delineate the frost affected part of the wheat paddock and advised the contract harvester to not harvest that part of the field. A different farmer arranged his harvest schedule according to information gained from imagery. He had delineated frost damage of approximately half of his paddock and left this part to be harvested last, and separately, thus not contaminating the quality of the non-frosted wheat crop; hence he received a higher financial return.

Other benefits of the early phase crop monitoring system ALMIS were that farmers had a visual historical record of their paddocks. Together with imagery obtained in other years, specific reoccurring problem areas in fields could be observed. Such information, obtained from several years is a basis for delineating paddocks in different management zones and applying site specific treatments.

The use of remote sensing imagery in agriculture has been reported by a vast range of authors, such as Dawson et al. (1998), Riedell et al (2000), Inoue (2003) and Thorp and Tian (2004) (also refer to Chapter 2). The literature mostly reported about scientific observations from researchers without participation of the potential users of the technology. Seelan et al (2003) however reported on the involvement of local farmers with the Upper Midwest Aerospace Consortium (in the USA) to test remote sensing for precision farming applications. Most of the case studies reported in the paper were observed in 2000 (while the field trials reported in this thesis were conducted in 1998). Seelan et al. (2003) also found that satellite remote sensing imagery could map nitrogen deficiency in sugar beets, *rhizoctonia* fungi (also in sugar beets), fungicide spray misses in wheat, armyworm infestation (also in wheat), aerial spray damage in sugar beets, need of drainage improvements in a wheat field and potato crop damage due to river inundation. Thus similar observations have been made in parallel studies in the US and Australia (this study) confirming the usefulness of remote sensing data for end-users (farmers).

8.5 Conclusions

In review of the 1998 Agricultural Land Management Information System early prototype testing, the following results were achieved. Twenty-five farmers from the Gooroc Farming community participated in the study and contributed at different levels of involvement. Several satellite operators supported the research initiative with free data. Extensive data collection took place with remote sensing imagery, as well as field work. Five colour-coded Vegetation Index images were delivered to the participating farmers. Areas that appeared different to the rest of the paddock were investigated. The vegetation index images showed potential to be a valuable tool for targeted scout walks and management decisions were modified as result of the information gained from satellite imagery.

The content of the information found in the vegetation index images was analysed and categorized in three areas: variability due to environmental factors (85 cases reported by the farmers), variability caused by insects, pests, diseases and weeds (27 cases) and variability due to farm management issues (137 cases). Various representative examples were included in this chapter.

In summary, the following problems could be detected in the satellite imagery of the crop:

- Soil type differences within the paddock
- Frost
- Armyworms
- Wireworms
- Slugs
- Aphids
- *Ascochyta* blight of chickpeas
- Phoma
- Weeds
- Consequences of historic management decisions (old fence lines, tree sites, refilled dams, old waterways, soil compaction due to agricultural vehicle traffic, mechanical soil shifting and levelling, old fire scars etc)

- Farming equipment errors (failure & double sowing, spray misses and over-spraying)
- Different management practices (seed rate & crop variety)
- Crop maturity levels for harvest scheduling

The capability of the SPOT remote sensing data to detect problem areas in broad acre grain fields is most valuable for precision farming applications to optimize variable rate technology applications and to delineate crop management zones.

9. Design of an improved crop monitoring system prototype integrating farmer's feedback and other findings from this study

9.1 Introduction

In the past Remote Sensing has provided valuable information on agriculture; however analysed information was often limited in access and used principally by scientists, policy makers and large organizations. Entering into the space age of farming, remotes sensing holds promises as a useful tool for precision agriculture, and to be used by the end-users, the farmers. In order to develop a valuable and usable tool the feedback of the farmers is essential in the product development. Thus in February 1999 a workshop was conducted with the participants of the ALMIS project. Different aspects of the 1998 trial were debated such as usefulness of the information content, timeliness of the data, delivery speed, cost benefit to farmers, GIS system, and map products, and more. Several fields of the farmers were discussed as case studies in interactive sessions; experiences with the crop monitoring vegetation indices were shared, and in-paddock variability samples were debated. The participants made recommendations for the future development of an operational crop monitoring system. These, together with the results gained form the ALMIS study and considerations reported in the literature were the foundation for the design concept of an improved version of a crop monitoring system. In this chapter the critical parameters for a satellite crop monitoring system are discussed. Conclusions from this research are not discussed in this chapter, but are presented in the final chapter of the thesis.

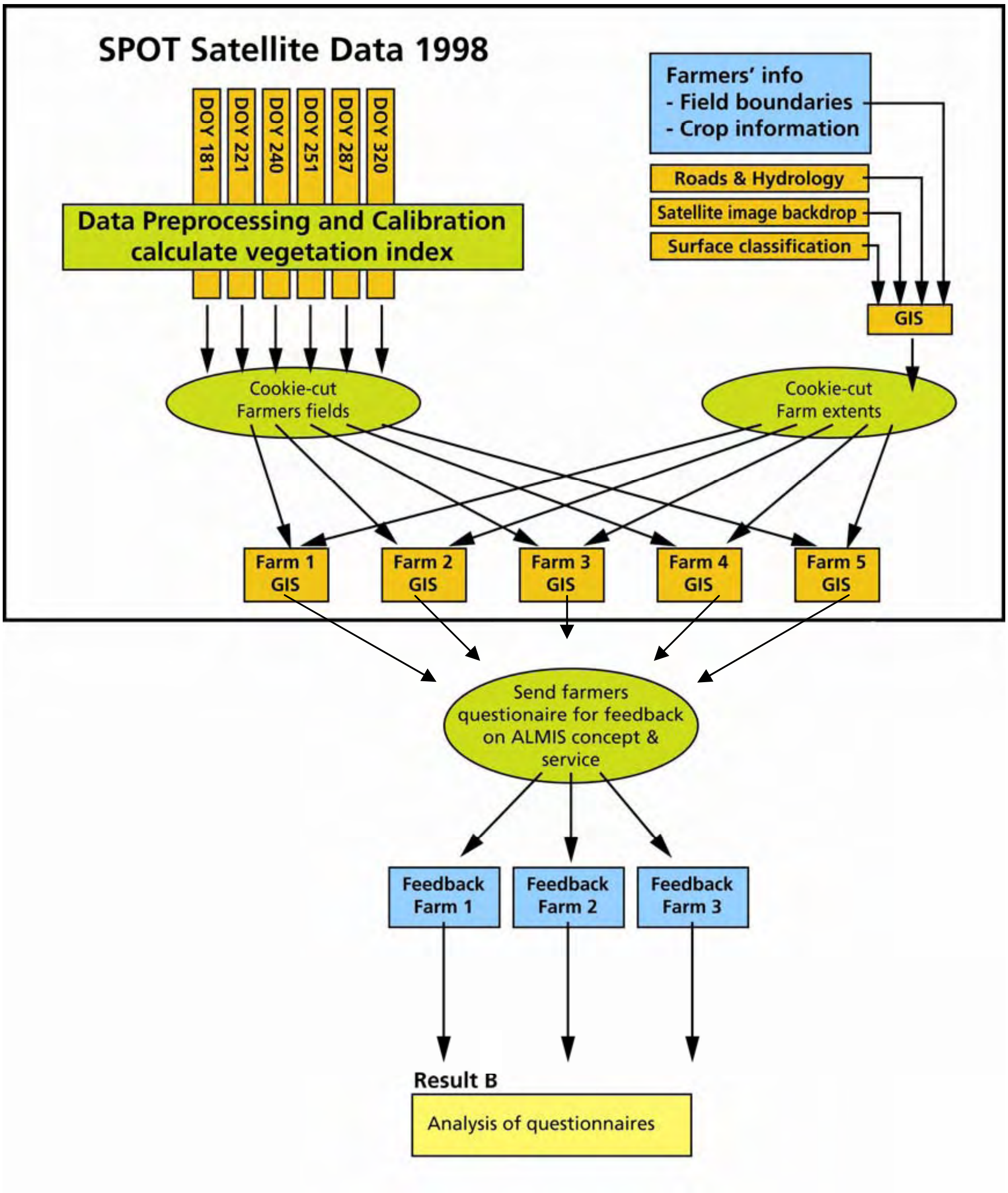


Figure 9.1: Overview of steps in receiving feedbacks of farmers on the prototype ALMIS crop monitoring system

The flowchart gives an overview of the methods, processing steps and results discussed in this chapter. The flow chart was colour-coded. Orange represented data and databases, and blue symbolized data which were obtained by interaction with the farmers. Green circles corresponded to processing steps while yellow denoted the results. See text for full explanation.

9.2 Methods

The participating farmers were asked to complete a questionnaire to evaluate the ALMIS project and to provide feedback, so their suggestions could be implemented into future versions of the crop monitoring system (see Figure 9.1 for overview of steps). The questionnaire can be viewed in Appendix A. Examples of questions included delivery speed, date specific information content, product quality, support, and format etc. A number of farmers only partially answered the questionnaire; hence the numbers are not consistent with the number of farmers that participated.

9.3 Results and discussion

9.3.1 Delivery speed

The first question concerned the delivery speed of the product from data acquisition to delivery at the "farm gate" (physical or "virtual" in terms of electronic delivery.) A delivery time within 7 days, for example meant that the satellite data were acquired on the 20th August and delivered on the 27th of August.

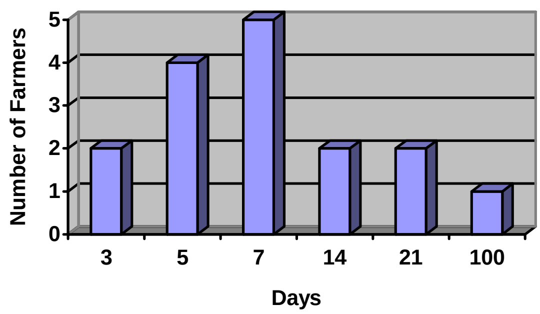


Figure 9.2: Delivery speed required by farmers

Most farmers (Figure 9.2) required the analysed information within one week after data acquisition (in particular in the early growing season between August and September) to be most useful for management purposes. One farmer required the information after harvest as historic paddock information (100 days).

9.3.2 Most relevant dates for information

The next question concerned the satellite acquisition dates, which provided the most relevant information for the farmers. Most farmers found the imagery in late July, and August to be most useful for management purposes.

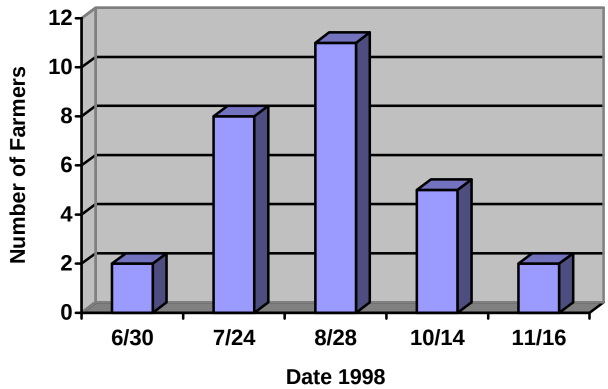
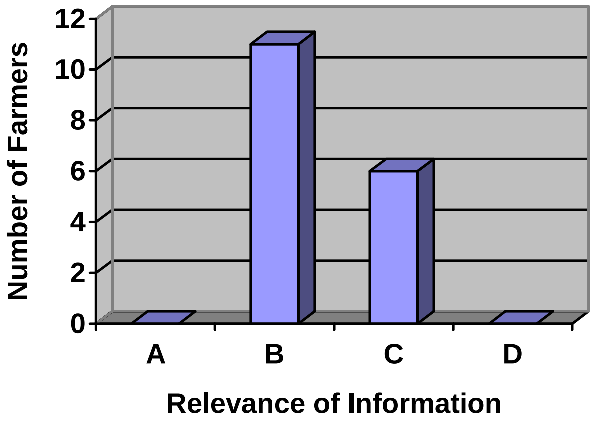


Figure 9.3: Relevant dates of satellite image acquisition

Comments on the kind of information learnt at those dates included: crop health, nutrients status, plant density, insect infestation, and seeder errors. It was also commented that the spatial extend of the frost damage and chickpea disease ascochyta blight could be picked up very well on the images later in the season. The 10 metres merged satellite product was in particular useful to detect hot spots and smaller areas of blight damage.

9.3.3 Product quality

The farmers were questioned about the newness and relevance of the information learnt from the crop monitoring information product. Most farmers found that by the time they received the information (which initially took a few weeks in 1998), they were aware of the problems in their paddock; however the VI product provided them with the exact location and extend of the problem.



A New information
B Relevant info about extend and location of problem
C No new info, but of value
D No new info, of no value

Figure 9.4: Relevance and newness of information

9.3.4 Product support

Farmers commented on the support received from the ALMIS team. The internal project support structure commanded that all communication with farmers was entered into a "communication log" and relevant tasks were managed through action lists.

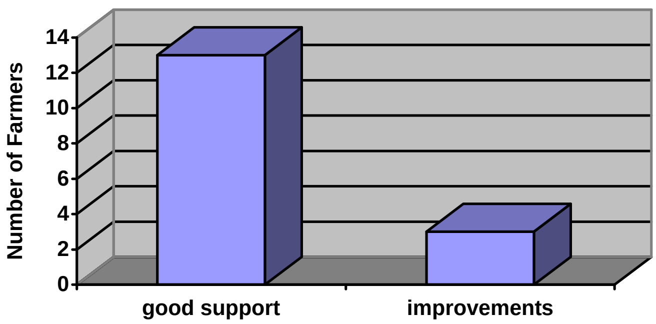


Figure 9.5: Product support from ALMIS team

Most farmers expressed that they were content with the support given by the ALMIS team; they found two workshops per season (one after the first image was taken and another one at the end of the season) were adequate. Three farmers suggested improvements, such as giving the computer illiterates tuition, and offering monthly workshops and follow-up phone calls. It should be noted, the later two suggestions were made from two farmers who did not have time to attend the training and the review workshop.

9.3.5 Price

This question concerned the perceived cost / benefit of the monitoring product. The farmers contributed AUD$ 200 towards the expenses of the workshop and image delivery.

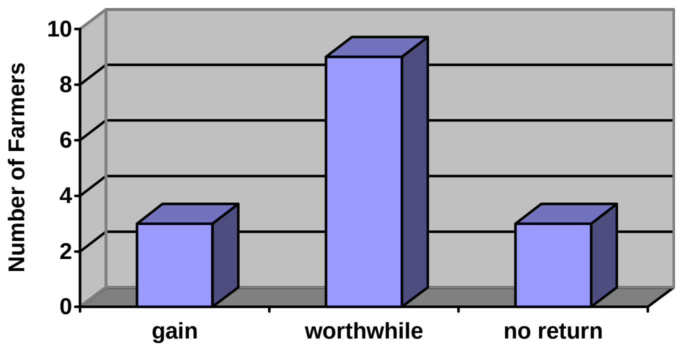


Figure 9.6: Perceived cost / benefit of monitoring product to farmers

Three farmers found that they got more benefit from the subscription than the costs incurred. One farmer even noted that he thought the price was very inexpensive for what was delivered. The majority of the farmers could not yet implement the information given in a cost-effective management practice, but thought the subscription money was spent worthwhile. Three farmers did not receive any return for their money, but commented that this was partially related to them having "a bad year" with their crop and the kind of problems they incurred.

9.3.6 Delivery format

The information was either delivered by e-mail, floppy disk, (in the mail for those participants with either no internet access or with unreliable country copper-exchange phone lines), and for farmers with no adequate computer access or knowledge as printed hardcopy maps. Ten farmers selected as their preferred media of delivery e-mail, 7 farmers requested a floppy disk in the mail and 8 farmers wanted only hardcopy prints. Several farmers tested multiple delivery methods. All farmers received hardcopy maps. Great flexibility of data delivery in 1998 was given to the farmers to ensure that the information was presented in a meaningful manner and to improve the products with the participant's feedback. In the future the media of delivery should be reflected in the pricing structure, as it is quicker (and therefore less costly) to utilize automated digital distribution than to print hardcopy maps and send the product in the mail.

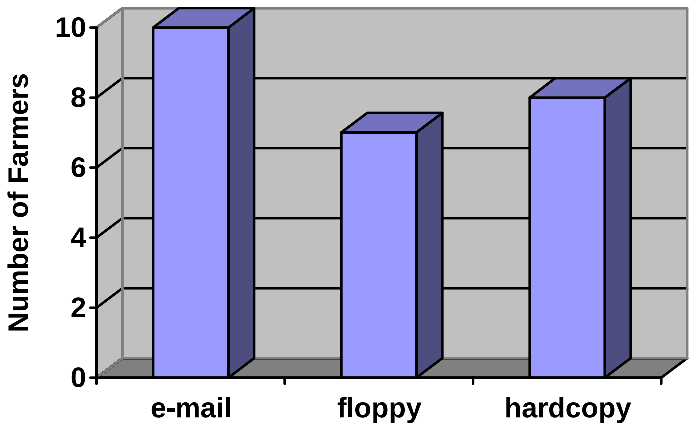


Figure 9.7: Preferred media of data delivery

Of the farmers, that provided feedback on the delivery mechanism, most were happy with the delivery options provided. Two farmers, however encountered problems with the electronic delivery (one of them also had floppy delivery as the preferred delivery option). Furthermore it was suggested to send hardcopy instructions for the installation, not just digital read-me files. Options of automated installation should be investigated.

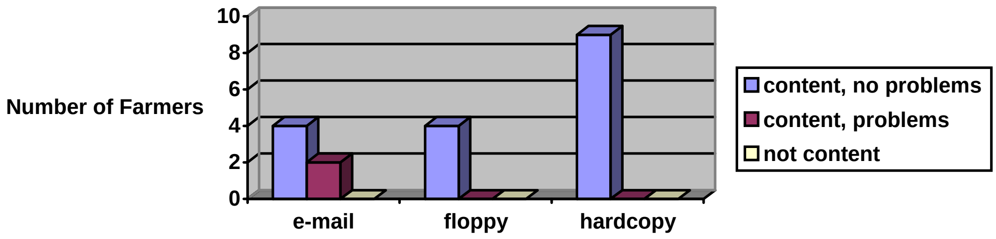


Figure 9.8: Participant satisfaction levels with the delivery mechanisms

Two sizes of hardcopy maps were delivered: A-4 format maps (each contained one or two paddocks per page) and 1:20,000 scale transparent VI overlays for the satellite backdrop hardcopy map.

Of the nine farmers that were content with the hardcopy map delivery, four preferred the small A-4 format maps as they found them to be portable. Another four preferred the big 1:20,000 scale images as they were easy to use and gave an overview of the whole farm at once. Two farmers were undecided and liked both versions. Problems were encountered with the delivery via Australia Post when two maps were lost; these had to be re-printed and re-sent. Hence the arrival of the hardcopy deliveries needed to be verified.

Furthermore, the farmers were asked to make suggestions to alternative delivery mechanisms they would like to see implemented. One farmer thought a “community PC and printer” in St Arnaud to which all participants have access would be beneficial. It was proposed to use the computer and internet access at the local library. Another farmer wished for the ALMIS team members to be available in person several times through the growing season to discuss the imagery, either in the Gooroc area or at the Melbourne office. Two farmers would like to be able to use a 1-800 telephone number when communicating with the ALMIS team. It was furthermore suggested to have access to a computer specialist that could assist farmers with lesser levels of computer literacy in the set-up and with technical questions. Five farmers were willing to pay a reasonably priced agronomist that was trained in interpreting satellite crop monitoring products and could assist them with appropriate management strategies.

9.3.7 Benefits

In this question the farmers evaluated the benefits they received from the information product. Six farmers initially had no tangible benefit. The reason therefore was long delays between data acquisition and delivery and hence the information was too old for management purposes. Another reason given was the difficulty in "reading" the information supplied (the farmer who made this comment did not have time to attend the training workshop). Amongst the benefits listed in the questionnaires were: One farmer found he could save costs, three could apply better management practices; Furthermore detection of disease and insect infestation, as well as the extent of frost damage was mentioned. Six farmers found benefit in having a spatial documentation of the "historic" events in the paddock for the 1998 season for future reference.

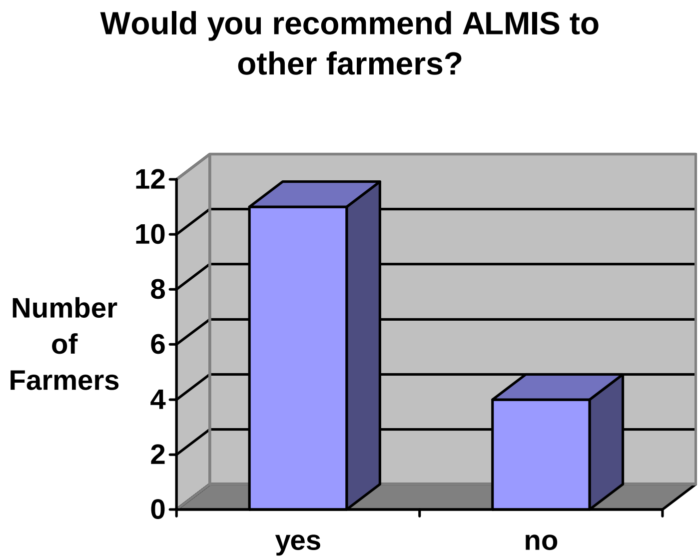


Figure 9.9: Farmer's recommendation of ALMIS

The majority of the participating farmers would recommend a satellite based crop monitoring system such as ALMIS to other farmers. The reason that four farmers would not recommend it was mainly the delay between data acquisition and delivery as experienced in the early parts of the 1998 crop season. One farmer thought the information needed to be available within 1-2 days of satellite overpass. Another farmer wanted to see it developed further before he would recommend it to other farmers. However, the majority of participants made very positive comments; several mentioned that "it was the future of farming" and that it was a good concept.

9.3.8 Future involvement with ALMIS

When the farmers were asked about their future involvement with ALMIS and if they would subscribe to another year at non-subsidized prices, the response was very positive.

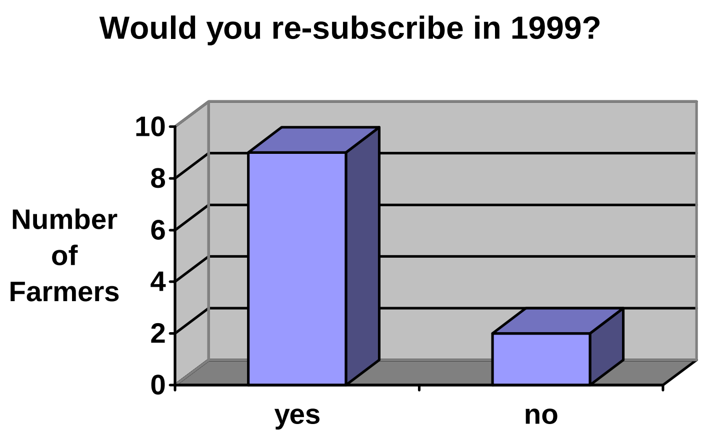


Figure 9.10: Renewal of subscription

Some were hoping for improvements, prior to them subscribing, in the areas of delivery speed, quantitative crop parameters, technical support and cost of service.

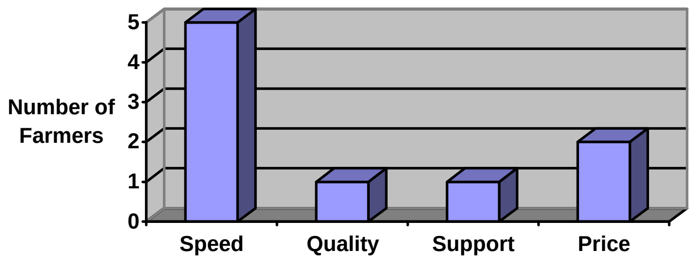


Figure 9.11: Improvements required for ALMIS

9.3.9 Summary of farmers' feedback

In summary it was identified that the most critical parameter for the crop monitoring service was the turn-around time between image acquisition and delivery to the farmers. Substantial improvements needed to be made from the satellite companies to speed up the process. The most useful information for paddock management decisions was found in imagery in late July to August. The vegetation index images were useful to see the location and extend of problems in the field and comprised a valuable scout tool. Farmers suggested that difference maps between the various acquisition dates would also comprise a valuable tool. Farmers wanted easy-to-use technology that automatically installed on their computer and assistance in interpreting the images and turning them into management decisions. Farmers furthermore needed help with (sometimes) basic computer tasks. Farmers with no access to computers wanted information in hardcopy maps and specific crop management recommendations of an agronomist. Some farmers were happy to pay for such a service. Even though farmers could see that satellite remote sensing can provide valuable information to them, financial benefit was not yet fully documented. This was due to the farmers finding it difficult to estimate savings as well as not sharing information on farm finances. However from discussions it was clear that most farmers were under substantial financial pressure (mainly due to recent climatically difficult farming years) and were hesitant to invest substantial amounts of money into precision farming tools and technology.

9.4 Consideration of critical parameters for prototype system

The issues and challenges for a satellite crop monitoring system that were identified from the literature (Chapter 2.4) were considered in light of the farmers' feedback on the ALMIS prototype. Considerations of critical parameters for a prototype system were data delivery times, satellite selection, data corrections, localized scientifically validated models, system technology, technology transfer and adoption.

9.4.1 Near real time data delivery

Problems occurred with the initial slow turn-around time between data acquisition and delivery of the analysed information to the farm gate. This time delay could be reduced significantly by the end of the 1998 season, but was the most noted complaint of the ALMIS participants. For paddock management purposes the crop monitoring information needed to be recent. The slow turn-around times were discussed with the SPOT image supplier ACRES and eventually digital cataloguing within hours of reception and the "STAR" service (electronic data delivery within hours of ordering at extra cost) was introduced. During the 2001 CropView project turn-around times from 1-2 days were reached consistently (CropView, 2003; Sobels et al., 2002). For instance, satellite data acquisition occurred around 10:00 am in the morning and the processed data were delivered to the farmers electronically by dinner time. In 2001 it was commented by farmers that such quick turn around time were commendable, but not necessary. Hence a turn around time for broad acre crop monitoring information of 1-2 days is satisfactory for farmers and can be achieved with today's technology.

9.4.2 Satellite selection

The satellite data used in 1998 were mainly multispectral images from SPOT 1, 2 and 4 with 20 metres pixel size. SPOT was chosen since it had a high revisit capability due to its off-nadir viewing potential. Since clouds were a concern during the crop season in south east Australian winter, SPOT allowed adequate temporal coverage of the test site. After the frost in October 1998, a SPOT panchromatic image (10 metres pixel size) was acquired approximately 2 weeks later to test higher image resolution by merging the panchromatic and multispectral imagery. Significant more detail could be observed in the merged image product (10 metre pixel size) which was particular helpful in the delineation of frosted areas and at the time prevalent crop disease ascochyta blight in chickpeas. A subset of farm 14 in 10 and 20 metres pixel size is given in Figures 9.12 and 9.13. Thus it can be seen that for broad acre precision farming applications image resolution of 10 metres or better are preferred to 20 metres resolution; crop problems could be picked up earlier and in consequence adequately addressed by prescription farming techniques.

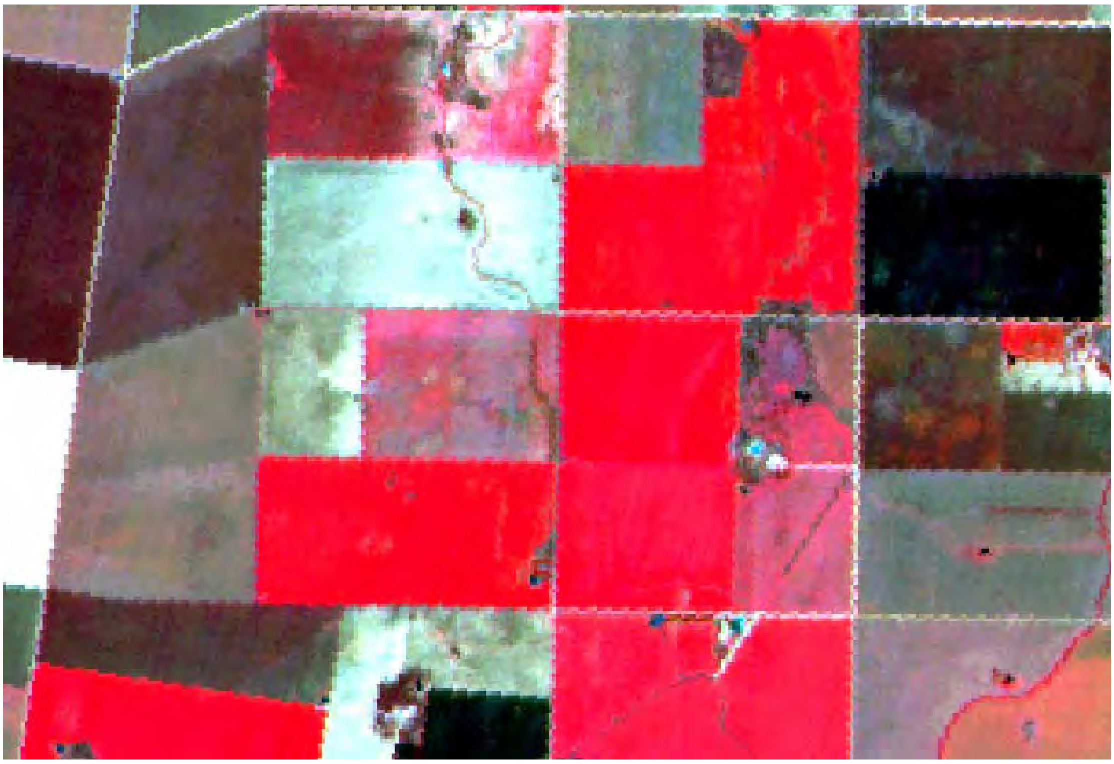


Figure 9.12: 20 metre multispectral SPOT image

Figure 9.13: Merged 10 metre multispectral and panchromatic SPOT image

Since the trial in 1998, new higher resolution satellites have been launched and image data are commercially available. Table 9.1 and Table 9.2 summarize details of such sensors.

Table 9.1: Current high resolution satellite systems (Source: ERSC, 2005)

Satellite Name	Source	Launch	Sensors	Types	No. of Channels	Resolution (meters)
IKONOS	Space Imaging	1999	IKONOS	Multispectral	4	4
				Panchromatic	1	1
QuickBird	DigitalGlobe	2001	Multispectral	Multispectral	4	2.44
			Panchromatic	Panchromatic	1	0.61
SPOT-5	France	2002	HRV	Multispectral	3	10
					1	20
				Panchromatic	1	2.5, 5
OrbView-3	Orbimage	2003	OrbView	Multispectral	4	4
				Panchromatic	1	1
FORMOSAT-2	Taiwan	2004	PAN	Panchromatic	1	2
			MS	Multispectral	4	8
IRS-P6 (ResourceSat-1)	India	2004	LISS 3/4	Multispectral	7	5.8, 23.5
			AWiFS	Multispectral	3	80

Table 9.2: VIS and NIR spectral band location in current high resolution satellite systems

Satellite Name	Blue Band	Green Band	Red Band	NIR Band
IKONOS	450- 520 nm	510- 600 nm	630- 700 nm	760- 850 nm
QuickBird	450- 520 nm	520- 600 nm	630- 690 nm	760- 900 nm
SPOT-5	N/A	500- 590 nm	610- 680 nm	780- 890 nm
OrbView-3	450- 520 nm	520- 600 nm	625- 695 nm	760- 900 nm
FORMOSAT-2	450- 520 nm	520- 600 nm	630- 690 nm	760- 900 nm
IRS-P6 (ResourceSat-1)	N/A	520- 590 nm	620- 680 nm	770- 860 nm

9.4.3 Data corrections

Spatial accuracy better than 1.5 pixel absolute error was achieved in the study and found necessary for precision farming applications. This spatial accuracy is particular important to farmers using prescription application. With the use of higher resolution imagery in the future it would be expected to improve the spatial error in terms of absolute measured displacement [metres].

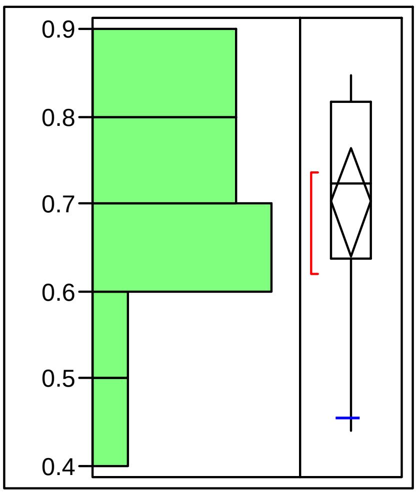
Radiometric and atmospheric corrections, based on the work of Richter (1996) were found to be most essential using multitemporal imagery (Chapter 4). The calibrations were indispensable for comparing satellite data points in absolute terms, such as spectral crop properties through-out the season as well as multi-seasonal comparison and parameter retrieval. Future applications of the models developed in this study require similar radiometric and atmospheric corrections.

9.4.4 Localized scientifically validated models

SPOT satellite data from 1998 and 2001 were used to derive a crop specific spectral baseline dataset at various points of their phenological development in the Gooroc area. This dataset is valuable to alert farmers to "atypical" fields which perform better or worse than average fields. Crop types can also be verified with the baseline dataset as crop parameter and yield estimates are crop type specific. Furthermore localized empirical regressions were obtained to estimate the crop parameters "height", "green biomass" and "dried green biomass", "spatial crop water content " and "percentile crop water content" for chickpeas. Farmers gained information on location and extend of problems in the field with the vegetation index image and 10-metre merged near infrared image. Farmers suggested the benefit of maps delineating change between two satellite acquisition dates and a rating how a paddock is performing compared to other paddocks of the same crop type in the area. Thus a product giving the percentile rating of each paddock was developed. Furthermore the differences between satellite acquisition dates were calculated for vegetation indices maps as well as quantitative crop parameter maps (for chickpeas). Lastly, the results from Chapter 7 were used to develop yield estimate maps for canola; hence a range of localized models were built in this work for precision farming applications. Examples of each information product are given as follows.

Percentile rating of paddocks

The percentile rating of paddocks measures how a paddock overall is performing when compared to other paddocks in the local area. An example is given in Figure 9.14. The Merrillees barley paddock (marked as blue line) was compared to other barley fields in the Gooroc area on the 28/8/1998. Merrillees had a vegetation index value of 0.44, which was on the very lowest quantile range (between 0-2.5 per cent), thus performing very poorly; this was caused by the armyworm infestation which decimated large amounts of biomass on the paddock.



Quantiles

100.0%	maximum	0.84823
99.5%		0.84823
97.5%		0.84823
90.0%		0.84152
75.0%	quartile	0.81600
50.0%	median	0.72284
25.0%	quartile	0.63671
10.0%		0.52562
2.5%		0.43988
0.5%		0.43988
0.0%	minimum	0.43988

Mean	0.7019421
Std Dev	0.1127147
Std Err Mean	0.0291028
upper 95% Mean	0.7643614
lower 95% Mean	0.6395228
N	15

Figure 9.14: Percentile rating of barley paddocks on 28/8/1998, including Merrillees paddock

Vegetation Index Difference Maps

The difference image calculates the differences that occurred in the satellite data between data acquisition dates:

Difference image=(Vegetation index image Date 2)–(Vegetation index image Date 1)

As an example the Merrillees barley field from 24/71998 and 28/8/1998 is shown in Figure 9.15 together with the resulting difference image. Green colour symbolizes increase in vegetation index values, while pink colours stand for decrease in vegetation index values. As a natural trend the barley plants grew in August (increase, green colours), while an armyworm infestation devastated large areas in the paddock, consequently reducing the amount of green barley biomass and thus vegetation index values (decrease, pink colours).

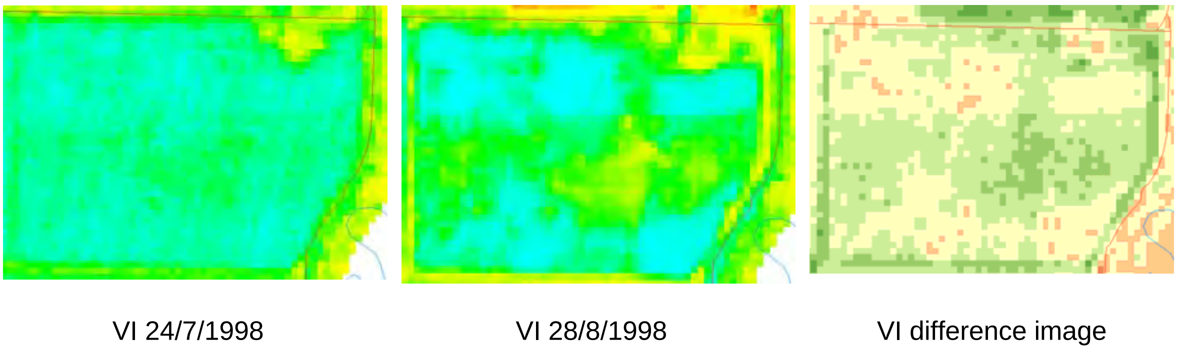
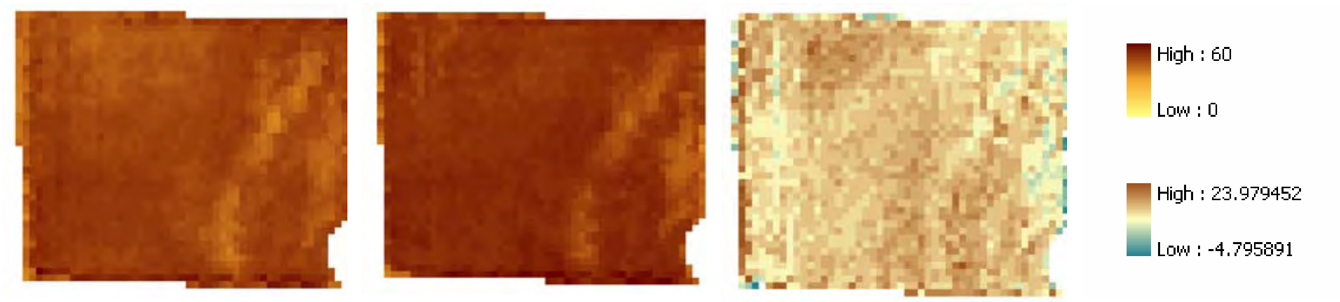


Figure 9.15 Merrillees field VI from 24/7/1998 and 28/8/1998 and VI difference image

Quantified difference images

When applying the difference image principle to quantified crop information as derived in Chapter 6, the difference in quantitative crop parameter between acquisition dates could be mapped. Figure 9.16- 9.19 shows the plant height (cm), above ground green biomass (g/m^2), dried green biomass (g/m^2) and plant water content (g/m^2) of the Gilmours' chickpea paddock on the 14/10/1998 and 16/11/1998. Furthermore the difference image for the crop parameters between the two acquisition dates was presented. The difference image instantly highlighted uneven crop development between the dates.



Chickpea plant height map 14/10/1998

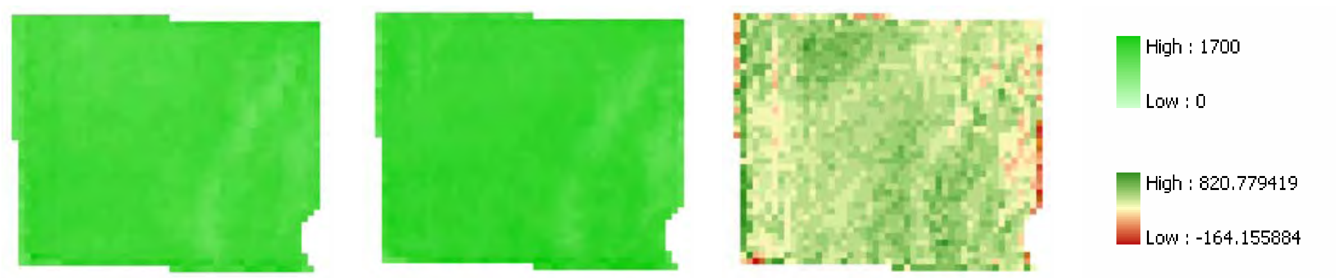
Chickpea plant height map 16/11/1998

Difference map chickpea plant height

16/11/1998- 14/10/1998

Legend for plant height and difference map (Units: cm)

Figure 9.16: Gilmours paddock, plant height maps



Chickpea green biomass map 14/10/1998

Chickpea green biomass map 16/11/1998

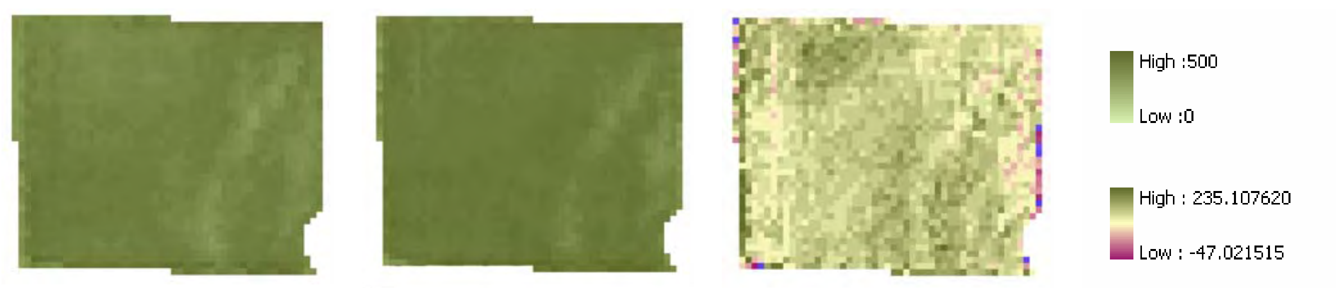
Difference map chickpea green biomass

16/11/1998- 14/10/1998

Legend for green biomass and difference map

(Units: g/m^2)

Figure 9.17: Gilmours paddock, green biomass maps



Chickpea dried green biomass map 14/10/1998

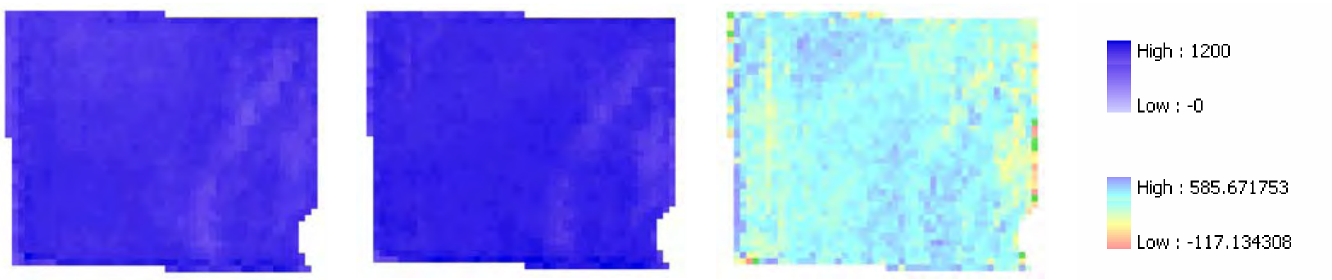
Chickpea dried green biomass map 16/11/1998

Difference map chickpea dried green biomass 16/11/1998- 14/10/1998

Legend for dried green biomass and difference map

(Units: g/m^2)

Figure 9.18: Gilmours paddock, dried green biomass maps



Chickpea crop water content map 14/10/1998

Chickpea crop water content map 16/11/1998

Difference map chickpea crop water content 16/11/1998- 14/10/1998

Legend for crop water content and difference map (Units: g/m^2)

Figure 9.19: Gilmours paddock, crop water content maps

In the digital version of the crop parameter and difference maps of the Gilmours paddock each individual pixel value can be queried with the "identify" tool in Arc Explorer. Some negative values appear on the edge of the paddock; these values are caused by land use other than chickpeas.

Crop yield prediction map

Crop yield estimation maps could be derived for canola as early as 09/08/1998 (with an accuracy of R^2= 0.71). An example of the Hoyes North canola paddock is shown in Figure 9.20, together with the yield map obtained at harvest on 02/12/1998 (Figure 9.21). In this case a wireworm infestation caused need for resowing of the involved areas; as a result of the delayed crop development these areas were affected by late frosts (dark blue), causing substantial yield losses.

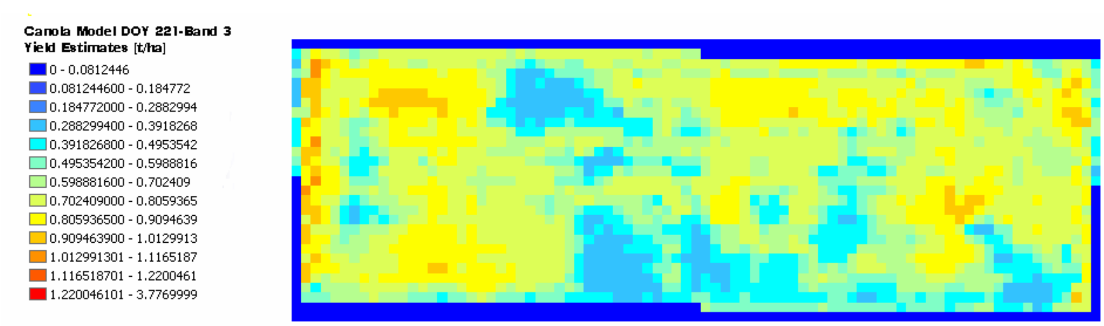


Figure 9.20: Canola crop yield prediction map Hoyes North paddock Model DOY 221-SPOT Band 3

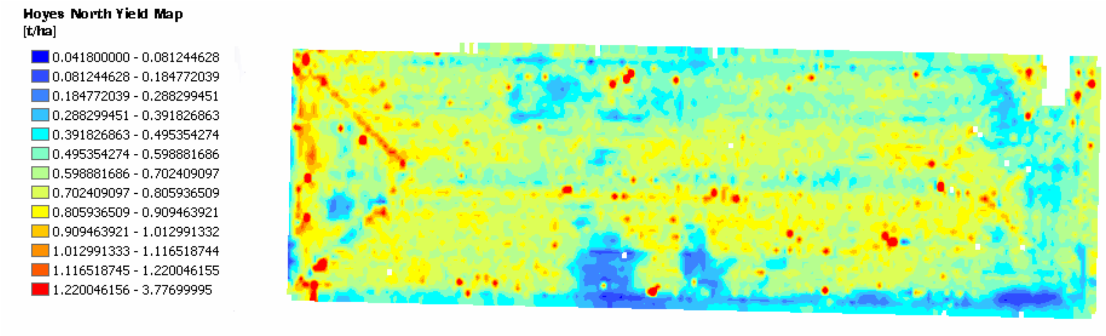


Figure 9.21: Canola yield map 1998, Hoyes North paddock

9.4.5 Development of system technology

In the 1998 ALMIS study the data were facilitated with the ARC Explorer software on the farmers' computer; Arc Explorer is a free basic GIS software package. Data provided to farmers consisted of a backdrop image, roads and hydrology and a surface classification of the paddock. The vegetation index images were supplied in a data format suitable for integration into ARC Explorer. Some farmers also used their own farm management software and obtained the vegetation index images as TIFF and BMP files. Increasingly farmers administrate their farms on the computer and use software packages such as for example PAM (Fairport, 2005) with the precision farming extension "Farmstar". Thus it is important that the data of the satellite crop monitoring system are compatible to such farm management software packages.

In 2002, ARC IMS (ESRI, 2002) was tested to edit paddock boundaries and administer satellite imagery. Instead of hosting the software and data on the farmers' computer, it was hosted on a server that the farmer accesses via the internet. This technology is much like internet banking. Farmers need an account on the server which is accessed via the internet. While ARC IMS performed well when accessed via a broadband cable connection, the access via a phone dial-in modem proofed difficult and too slow. In particular the backdrop image that was needed for orientation and for the initial paddock digitizing was very slows to transfer via the phone modem. If farms connect to the internet via a radio dish to communication satellite downlinks, fast enough connections could be achieved to utilize the ARC IMS technology. At this stage costs of such a system are still prohibitive, costing approx. $100,000 for a communal satellite downlink and backbone infrastructure and an additional $700 per farm (together with ongoing data cost, which is less than broadband internet costs in the capital cities though); however there are government grants available for rural Australian telecommunication proposals and as technology advances it is expected that most farms will be connected to the internet with fast access within the next 7 to 10 years (personal communications P. Richards, 2005). Using client- server technology allows automation of multiple components, hence enabling the system to service multiple farmers at a reasonable administration cost. Farmers would be able to set up their own account, digitize their own paddock boundaries, attribute paddocks, and view vegetation index images. With arrival of the latest satellite data in the system, farmers could be notified by email or SMS. Furthermore, farmers could use a payment gateway (personal communication L. Coppa, 2005) to purchase services electronically with their credit card.

9.4.6 Technology transfer

As precision farming techniques - in particular crop monitoring using remote sensing data - are relatively new to farmers and their advisors, education is needed. During the 1998 trial several workshops were held and basic principles of remote sensing and precision farming were taught. Nevertheless farmers needed individual attention to understand the satellite images. A system with a remote (possibly city-based) call centre to support the satellite imagery is most unlikely to succeed. Farmers like social contact and advices from trusted sources, such as their agronomist. Hence the agronomist is the ideal person to utilize satellite imagery and familiarize the farmer with the data. The agronomist would have an additional service to offer to farmers, and can facilitate hardcopy maps for less computer literate farmers. Agronomists, however, are usually not trained in the use of satellite remote sensing data. Zhang et al (2002) noted that there is need for the conservative consultancy sector to receive appropriate training in order to advice their clients (farmers) on precision farming applications. Most agronomists had tertiary training in the past, and therefore are expected learn quickly in extension courses. Given adequate financial rewards from the additional services supplied using a crop monitoring system, it would be expected that agronomist are interested in offering this technology to their clients. Appropriate training courses and extension programs for agronomists need to be offered from the TAFE sector (Neale et al. 2001). Agronomists in return can educate the end-users giving one-on-one advice or by facilitating course for their clients. In Australia primary producers and rural land managers can receive financial assistance from the FarmBi$ initiative to undertake business and natural resource management training and education activities. The subsidy support is 50% of the eligible cost of the activity (for Indigenous participants the subsidy support is 75%). AAA FarmBis is part of the Australian Government's Agriculture Advancing Australia (AAA) package, and is a jointly funded State-Commonwealth national program (FarmBis, 2005).

9.4.7 Adoption of technology

For a wide adoption of the technology to occur by farmers, concrete financial advantages have to be documented (Seelan et al. 2003). There are no detailed studies on cost saving with satellite crop monitoring available in Australia as yet. In the ALMIS study most farmers did not disclose sensitive information about the dollar value of cost savings nor their farm financials. Farmers were hesitant to disclose savings as they assumed this information would have consequences on pricing of a crop monitoring service in the future. Since farm economic research was not the focus of this study, disclosure of finances was not a condition for participation. One farmer commented that he should be paid for sharing his observations with the satellite imagery as he was contributing to the development of a new marketable technology and acted as a guinea pig in experimental trials. Most likely a trade-off in a future study focusing on the benefit in farm economical terms when utilizing satellite crop monitoring technology could produce the much needed economic data: farmers receive the crop monitoring satellite data free in return for disclosure of financial savings.

The question arises of who should pay for a crop monitoring service. It is a new technology and its adoption is still in the infancy stages in Australia as for most farmers satellite crop monitoring is still unproven on their own land. Overall, the crop monitoring service has to be reasonably priced, to be affordable to farmers and to encourage adoption by trial. As a satellite based crop monitoring makes prescription farming a real possibility which assists the preservation of natural resources, it should be considered not only in the farmers', but also in the public interest. Weather forecasts, for example are freely available. Many farmers struggle to keep their farm and experience financial set-backs particular during extended drought times. Often any extra expense, such as for a user-pays service of a crop monitoring service is too much. Possibly a stricter legislative framework for environmental preservation on farm land, supported by subsidized tools for farmers to achieve such goals is the way to the future for Australia.

10. General Discussion

10.1 Introduction

This thesis investigated the use of remote sensing data for broad acre grain crop monitoring in south east Australia. The aim was to develop a concept for an operational satellite crop monitoring system that could assist farmers and land managers to better manage their crops.

In answer to the research questions:

- The spectral properties of "typical" barley, canola, chickpea, lentil and wheat crop signatures were described. The crop types could be distinguished using discriminate function analysis. A table with accuracies for the different acquisition dates was supplied.

- The crop-parameters "plant height", "above-ground green biomass", "dried green biomass" and "plant water", plus soil moisture parameters were correlated to the satellite data, with varying results. Strong correlations were found for chickpeas between the satellite data and most crop parameters. Plant water [g/m^2] and satellite data were correlated for all crop types.

- The Pearson Product Moment coefficient of single date satellite and yield data were calculated for all crop types (but barley due to lack of data). The results were summarized. Furthermore standard least square models, using satellite data from multiple dates were developed. The yield prediction model accuracies ranged from R^2=0.62 (wheat, including frosted fields) to R^2=0.88 (canola).

- Remote sensing could contribute valuable information for precision farming. Multiple examples of changed management decision by farmers due to information gained by the early phase prototype crop monitoring system were recorded. Critical parameters were adequate spatial and temporal resolution, stable radiometric and atmospheric image calibrations, electronic delivery within one to two days of data acquisition, meaningful parameters, adequate support and for farmers affordable price.

10.2 Synthesis of major findings

In review of the 1998 Agricultural Land Management Information System (ALMIS) early prototype testing, farmers saw the potential offered by a near real-time crop monitoring system. Twenty-five farmers from the Gooroc farming community participated in the study and received Vegetation Index images. Achievements were made in the following areas: establishment of a SPOT spectral database throughout the season for barley, canola, chickpeas, lentils and wheat; crop types could be distinguished; crop parameters and yield were correlated to satellite parameters; close cooperation took place with the farmers to learn from their feedback throughout the crop growth cycle and to develop information products that met their needs.

10.2.1 Spectral properties of crops in the Gooroc area

From the multitemporal SPOT 1998 satellite imagery spectral measurements for band 1 (green), band 2 (red) and band 3 (near infrared) were retrieved for the crop types barley, canola, chickpeas, lentils and wheat. Chickpeas and lentils were found to be distinctively different to barley, wheat and canola. Together with their respective NDVI values all crop types could be visually distinguished in the graphs. A discriminant function analysis was applied to the dataset and classification accuracies were obtained for each acquisition date. Using datasets from multiple dates, the classification accuracies could be improved significantly. For details of the classification results for each crop type and date refer to Chapter 5. The data were compared to a similar dataset from 2001 and equivalent spectral properties and classification results were found. However, sowing occurred later in the 2001 season and hence a temporal "shift" was seen in the satellite data. This shift was not found to be linear throughout the season and most likely compose difficulties when translating classification models from one year to the next. It is anticipated that crop signatures in other south east Australian regions under similar cropping systems and soil types are comparable to the ones observed in the Gooroc area. However this will need to be confirmed.

10.2.2 Parameter estimation from satellite data

The parameters "crop height", "above ground green biomass [g/m^2]", "above ground dried green biomass [g/m^2]", "plant water [g/m^2]", plant water content [%] as well as "volumetric soil moisture content [%]" and "available soil water from 0-100 cm depth [mm]" were collected throughout the 1998 season. The field data were presented and discussed. SPOT satellite data for band 1- 3 were simulated for each day in the crop season by linear temporal adjustment. From the satellite data the vegetation indices NDVI, DVI, RVI, SAVI and TVI were calculated. The Pearson Product Moment coefficient R was calculated for the field work parameters and the simulated SPOT data of the corresponding date.

The most significant result to report was that almost all field work parameters of chickpeas (other than plant water content [%], and available soil water [mm]) were highly related to the SPOT data. This was explained with the linear behaviour of the chickpea field measurements and the SPOT data over the season as well as a linear correlation of the plant parameters of chickpeas to each other. Thus regression functions with good fits could be retrieved for most of the plant parameters of chickpeas. The other crop types matured and reached senescence. Results might be improved by incorporating the phenological aspect in regression functions or formulating two regression functions for the crops, one covering the time frame before the VI maximum and another thereafter.

For the parameter "plant height" chickpeas were highly correlated to SPOT Band 3 and all vegetation indices, with a best result of R=0.96 (band 3). A linear regression function with R^2= 0.914 was fitted. An "above ground green biomass**"** regression model was retrieved for chickpeas (R^2= 0.82, band 3) and lentils (R^2=0.70, band 3). "Above ground green dried biomass" could be estimated for chickpeas with a linear regression model with R^2=0.83 (Band 3). The parameter "spatial plant water" showed more or less strong correlations for all five crop types. A generic model for all crop types was fitted with R^2= 0.52 (band 3), as well as crop specific regression models for chickpeas (R^2=0.80, band 3), lentils (R^2=0.68, band 3) and canola (R^2=0.54, band 3). "Percentile plant water content" and the remote sensing data were not found to be related for chickpeas. However, wheat (R=0.73, DVI) and canola (R=-0.75, band 3) showed some correlations. "Volumetric soil moisture content" and the SPOT data showed negative correlations for chickpeas (R=-0.86, NDVI) and lentils (R=-0.74, Band 3). This was explained by the canopy closure of these two crops occurring later in the season; hence the soil component was contained in the pixel reflectance value. The reflectance value of the soil component was influenced by the soil moisture (in general wetter soil appears darker, having lower reflectance). The absolute amount of "available soil water" could not reliably be modelled from the satellite data.

It is expected that the regression models for chickpeas produced by this research can be transferred to other years if calibrated SPOT data are used. This will however need to be tested. If sensors with system configurations (wavelength, band width) other than SPOT are used, the models most likely need to be adjusted.

10.2.3 Yield estimates from satellite data

Yield values from 558 areas of interest of 17 yield maps were extracted. For each crop type (other than barley) the Pearson Product Moment coefficient R was calculated for the pairwise correlation of yield and SPOT band 1-3 and the vegetation indices NDVI, DVI, RVI, SAVI and TVI. High values of R were found for canola in band 3 and most vegetation indices on all dates except on DOY 320 (just prior to windrowing). A linear regression model was fitted with R^2= 0.71 (Band 3) as early as DOY 221 (9/8/1998), and R^2=0.72 (band 3) on DOY 251 (8/9/1998). For detailed results of R for each image acquisition date refer to Chapter 7. A forward stepwise modelling approach was applied to the canola dataset (utilizing all satellite data parameters from all dates) and an improved standard least square model utilizing 14 satellite data parameters was derived with a R^2=0.88. Using only the 3 SPOT bands a R^2=0.87 was reached. Chickpeas and wheat did not show strong single date correlation, however when applying the stepwise modelling approach, standard least square models including all satellite parameters of R^2=0.80 for chickpeas (R^2=0.57 for band 1-3 only) and R^2=0.62 for wheat (0.53 for band 1-3 only) could be formed. When removing the data from the wheat paddocks that were noted as having incurred frost damage, the wheat model could be improved to R^2=0.68 (R^2=0.63 for band 1-3 only). Lentils showed good single date correlations from DOY 240 onwards; however the dataset had only 16 sample points. A stepwise model approach resulting in a standard least square model obtained a R^2=0.86 (R^2=0.84 for band 1-3 only). The robustness of the model for lentils in particular needs to be tested in the future.

All models need to be tested on datasets of other years. It is anticipated that the seasonal shifts between the years might create some problems. It needs to be investigated if the datasets can be adjusted to a "standard" reference year or if in the seasonal shift in itself information on yield is contained. Other approaches to estimate yield from satellite data could be to utilize a local agro-meteorological crop yield model and fine tune it with accounts of observed in-paddock variability. The utilization of low spatial resolution satellite imagery with high temporal resolution (such as MODIS) to observe the seasonal crop developments together with monthly high spatial resolution imagery to determine within- paddock variability should also be investigated.

10.2.4 Prototype "ALMIS" crop monitoring system testing

The early-phase prototype crop monitoring system ALMIS was tested by 25 farmers in the Gooroc area. Farmers were supplied with simple GIS software together with a dataset specific to their farm extent. The data included: 1:25,000 roads and hydrology, a merged 10 metre resolution image backdrop, a surface classification of their paddocks (which was related to soil type if bare soil was exposed at the time of data acquisition), and an attributed vector layer of the field boundaries, containing information on paddock history. Throughout the 1998 crop season five vegetation index images (based on NDVI) of the paddocks were delivered in most cases electronically, and as hardcopy maps in the mail. The farmers checked the vegetation index images in the field and noted reasons for in-field variability.

As a result of the ALMIS trial, changed farm management techniques due to the information gained from the satellite imagery could be reported. For instance one farmer had an armyworm infestation of his barley crop. He was aware of the infestation, but the vegetation index image showed him the exact extent of the problem. Instead of eradicating the armyworms and fostering a reduced area of crop to maturity, he recognized that the better and more viable approach was to kill the crop and manage the paddock for a weed problem and preserve soil moisture for the following year. Another farmer could see the exact extend of the ascochyta blight fungal disease in his chickpea field. He realized that the cost of harvesting the non-affected crop was higher than not harvesting the whole paddock. The same farmer could delineate the frost affected part of the wheat paddock and advised the contract harvester to not harvest that part of the field. Frost could be delineated by several farmers. One particular farmer arranged his harvest schedule according to information gained from imagery. He had delineated frost damage of approximately half of his paddock and left this part to be harvested last, and separately, thus not contaminating the quality of the non-frosted wheat crop; hence he received a higher financial return. Other benefits of the early phase crop monitoring system ALMIS were that farmers had a visual historical record of their paddocks. Taking into account imagery obtained in later years from CropView, specific reoccurring problem areas in fields could be observed. Such information, obtained from several years is a basis for delineating paddocks in different management zones and applying site specific treatments. The vegetation index images gave the farmers opportunity for targeted scout walks. Areas that appeared different to the rest of the paddock were investigated.

10.2.5 Farmer evaluation of ALMIS prototype crop monitoring system

The feedback received by farmers criticized the initial slow turn-around time from data acquisition until delivery of the analysed information to the farm gate. This time delay could be reduced significantly by the end of the 1998 season, but was the most noted complaint of the ALMIS participants. For paddock management purposes the crop monitoring information needed to be recent. The slow turn-around times were discussed with the SPOT image supplier ACRES and during the 2001 CropView project turn-around times from 1-2 days were reached consistently and found to be appropriate by farmers. In 1998 some participating farmers did not have computers, internet access, or computer literacy. The delivery of hard copy maps in the mail proofed to be very time consuming and difficult on an operational level. It is anticipated that the use of computers will steadily increase as has been seen in the last few years; particular farmers that are willing to adopt advanced precision farming technology, such as a crop monitoring system are becoming progressively computer literate. Farmers initially found it difficult to interpret the vegetation index images; therefore training courses were needed to familiarize the farmers with the basic principles of remote sensing underpinning the technology. Overall, farmers saw the potential offered by a near real-time crop monitoring system. For a wide adoption of the technology to occur by farmers, more concrete financial advantages have to be documented in Australia and the cost of such a service has to be reasonable, in particular as many farms experienced financial hardship in recent years.

10.3 Challenges and future directions

The following parameters were identified to be critical for a satellite crop monitoring system for precision farming:

- Turn-around time between data acquisition and delivery to the (virtual) farm gate needs to be within 1-2 days

- Satellite imagery should have spatial image resolution of better than 10 meters, have a narrow red band centred around 670 nm, and a near infrared band centred around the red edge (820 nm), with good temporal resolution, near real time electronic data delivery and attractive pricing structure

- Data pre-processing should reach absolute geometric accuracies of 1.5 pixels and radiometric stability of invariant targets of 5% reflectance

- Software for satellite data viewing needs to have automated easy installation; satellite monitoring maps need to be in appropriate format for integration in existing farm management software packages; to farmers with fast internet access a client-server solution (much like internet banking) could be offered

- The components that are offered in the farm monitoring system should consist of near infrared imagery, colour-coded vegetation index, percentile rating of paddock (to compare with other paddocks in the area), quantitative vegetation parameter maps (crop height, biomass, water content) and yield forecast maps. The acquisition date of the satellite imagery needs to be carefully timed and adopted to seasonal shifts.

- Assistance was needed for interpretation and in particular in converting the information into management decisions. Trained agronomists seemed to be most suitable for the task.

- Extension courses covering satellite crop monitoring technology and applications need to be offered by TAFE colleges to train agronomists and enable them to assist farmers using crop monitoring tools. This will give trained agronomists a cutting edge over competition and extra services to offer to their clients. Furthermore agronomists can facilitate hardcopy maps to farmers with minimal computer literacy.

- Local farmers should be offered education in basic technologies (Remote Sensing, GIS, VRT) underpinning a satellite crop monitoring service and precision farming; training courses can be government subsidized with the Farmbis program.

- There needs to be consolidated strategic efforts to develop VRT applications that utilize satellite crop monitoring information; thus maximal benefits and cost savings from optimized fertilizer and chemicals use become available to farmers. This will simultaneously benefit the environment.

- Technology acceptance is still in infancy. It needs to be supported by government and industry initiatives to reach critical mass and to be affordable to farmer.

The critical parameters of a satellite crop monitoring system have been identified in this study. The technical components can be mastered, as demonstrated; however there is substantial work ahead to train the distribution channel and the end-users. The slow Australian uptake of precision farming technology has been influenced by the weak economic position of many farmers in south east Australia in the last 7 years. The author believes that it is therefore most critical for policy makers to subsidize the cost of this technology until it reaches critical mass as it will not only benefit the farming sector, but also the long term sustainability of valuable natural resources.

10.4 Future research

To further develop an operational crop monitoring system using remote sensing data further, future studies should investigate:

- Spectral properties of other crops grown in south east Australian cropping regions

- Spectral properties from crops of similar cropping systems grown in other areas need to be compared to the Gooroc dataset to confirm the validity for other regions in south east Australia

- Spectral properties from several seasons need to be investigated to create a baseline data set and to clearly understand the effects of temporal shifts within seasons; the inclusion of agro-meteorological data should be investigated

- Hyperspectral data should to be analysed to gain a high spectral resolution dataset of crops in south east Australia

- Other satellites systems (such as radar and high spatial resolution data) need be investigated for their usefulness in a satellite based crop monitoring system

- The regression functions derived for crop plant parameters need to be tested in multiple years, in the Gooroc area and other areas in south east Australia; more advanced statistical functions should be investigated to better model non-linear crop development

- Yield models derived from the 1998 data need to be verified over multiple years, in the Gooroc area and other areas in south east Australia

- The extension of the yield model by integration of daily MODIS data

- The extension of the yield models by integration with agro-meteorological models

- Use of other datasets such as DEMs, EM-31 and airborne geophysical data together with satellite remote sensing data in a decision support system

- Test an advanced web-based client –server system to propagate crop monitoring system information in a rural environment; consider communal use of communication satellite downlinks for fast web access

- Detailed economic analysis of crop monitoring system benefits

- Develop handshake technology between satellite derived maps, VRT application maps and VRT hardware

- Best practice to educate user community in respect to satellite crop monitoring systems

Future research to further develop a satellite based crop monitoring system needs to investigate the validity of this work for other regions and seasons in south east Australia. The system needs to be extended to other crop types, and the benefit of other sensor systems and data sets needs to be considered. Finally different aspects related to the usefulness of the data to the end users need to be developed further for the crop monitoring system to become a vital part in a widely used agricultural decision support system. The work of this research is a significant contribution in developing the remote sensing concept for the most commonly used grain crops in south east Australia.

10.5 Conclusions

This study was first to test a prototype crop monitoring system in south east Australia and to deliver analysed satellite imagery to a local broad-acre grain crop farming community via the internet on multiple dates throughout a complete vegetation growth cycle. Baseline spectral crop properties could be derived for five crop types in the area; furthermore selected plant parameters could be estimated, in particular for chickpeas. Yield could be estimated prior to harvest, especially for canola. The ALMIS early prototype trial demonstrated the benefits of satellite crop monitoring giving practical examples of modified agricultural management practices resulting in economic benefits for local farmers. The technology developed in this thesis contributes to the Australian goal of increasing crop yields in a profitable and environmentally friendly manner.

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Appendix A

ALMIS Feedback Questionnaire

Your Name: ____

Address: ____

Thank you so very much for taking time to help us learn how we can make ALMIS more useful to you! We value your input very much and will try to integrate your suggestions in the next versions of ALMIS! Please feel free to add comments next to any of the boxes you ticked. Thank you! ☺

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DELIVERY SPEED

Everyone would like to have an image as soon as possible, however there are issues of technical feasibility and the cost involved. We might be able to deliver within 3 days, but the product becomes so expensive that is not worth it for you. The same product could be delivered much cheaper with a 2 week waiting period. Please indicate in what **maximum time frame** the product is most useful to you for management purposes.

I <u>must</u> have the product in my hands

☐ 3 days after satellite - overpass
☐ 5 days after satellite – overpass
☐ 1 week after satellite – overpass
☐ 2 weeks after satellite - overpass
☐ 3 weeks after satellite – overpass
☐ 4 weeks after satellite – overpass
☐ after harvest, for record keeping only

****

Timeliness

Please indicate which satellite **date** gave you the **most important** information

- ☐ June 30
- ☐ July 24
- ☐ August 28
- ☐ October 14
- ☐ November 16

What kind of **information** did you learn at that date?

____

****

Product Quality

The **ALMIS monitoring product** (Vegetation Index)

- ☐ Gave me some useful information about things going on in the paddocks that I did not know on the day of data acquisition

- ☐ I knew what was going on in the paddocks, but the Vegetation index map gave me the exact location and the extent of the problem

- ☐ There was nothing new I learned from the ALMIS monitoring product, but it was still of value to me

- ☐ There was nothing new I learnt from the ALMIS monitoring product and I am disappointed with the product

Your **recommendations** to improve the ALMIS monitoring product (Vegetation Index)

____

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PRODUCT SUPPORT

☐ I thought the ALMIS team supported me **well** with newsletters, phone calls/ availability in technical questions and workshops

☐ The ALMIS team **could improve** their product support. Please tell us how

____

****

PRICE

☐ The subsidised ALMIS monitoring product was a bargain. I got a lot more benefit out of it than the subscription costs

☐ The subsidised ALMIS monitoring product did not give me a lot of benefit, but I got my moneys worth

☐ The subsidised ALMIS monitoring product did not give me any returns for my money

Comments: ____

****

DELIVERY FORMAT

Which delivery format did you choose?

☐**e-mail**

☐I liked the e-mail delivery and most of the time I did not incur problems in the down-loading

☐I liked the e-mail delivery but down-loading often was a problem.

What **modem line speed** for data transfer do you usually obtain? ____________________

☐**floppy**

☐I was **happy** with the floppy delivery

☐I was **not** happy with the floppy delivery

Please tell us why______________________________________

☐ **hardcopy maps**

☐ I was **happy** with the hardcopy maps

☐ I was **not** happy with the hardcopy maps

Please tell us why______________________________________

Map size

☐ I preferred the A4 map size

☐ I preferred the big overlay map size

Please tell us why______________________________________

Would you like to see any **other** delivery mechanism? Please indicate your **preferred** delivery mechanism:

☐ E-mail

☐ Floppy Disk

☐ Hardcopy Maps

☐ Local PC in the St Arnaud area where I can go and look at my data and print the maps I want myself

☐ Local Consultant, who visits me, shows me my data and prints the paddocks I want on the spot (I am willing to pay some extra for consultancy fees)

☐ Internet download facility from the ALMIS Home Page

☐ Other: ____

****

BENEFITS

☐ I got **no** tangible benefits from the ALMIS monitoring product

____

☐ I got tangible benefits from the ALMIS monitoring product:
Please **number** the **order of importance** to you

☐ Cost saving. Please tell us how (saving chemicals, harvest frosted areas separate etc) and how much $$ you saved.
_____________________________ approx. $ ________

☐ Better Management (better understanding & monitoring of processes in paddocks). What did you manage different with the help of ALMIS

____

☐ Identification of weeds ____________________________________

☐ Identification of disease ___________________________________

☐ Identification of insect damage______________________________

☐ Better documentation for future reverence __________________

☐ Other (Please explain)____________________________________

I would recommend ALMIS to other farmers

☐ Yes
☐ No

Why? ____

****

RESEARCH SUPPORT

The information you supply on your paddocks is most important for the research aspect of ALMIS. We learn what we can see with satellite data and this assists us to develop, improve and test mathematical models to monitor healthy crop growth. Your data are only used for research purposes and are treated confidentially. We understand that there was/is a lot of work involved retrieving that information for us and greatly appreciate all your effort!

☐ I have submitted the questionnaire with the paddock history

☐ I have not submitted the questionnaire with the paddock history yet, but will do so in the soon future

☐ I will not submit the questionnaire with the paddock history (please tell us why) because ____

****

YOUR FUTURE INVOLVEMENT IN ALMIS

☐ Yes, I would like to subscribe to ALMIS in 1999

☐ No, I would not like to subscribe to ALMIS in 1999. Please tell us why

____

☐ I would only subscribe next year if you significantly improve

- ☐ Delivery speed
- ☐ Quality
- ☐ Support
- ☐ Price
- ☐ Other: __________________________________

Please explain in your own words what in particular we need to improve in order for you to subscribe again

____

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Other Comments: ______________________________________

Appendix B: ERS Radar Data

The author was a Principal Investigator with the ESA AO-3 program (project AO3-378: Development of an Operational Crop Monitoring System in the St Arnaud Area, Victoria (Australia), using ERS SAR Data) (Coppa, 1997). Fifteen ERS-2 scenes were acquired in 1998 and 1999, and extensive fieldwork was conducted at the time of ERS-2 data acquisition. Originally it was anticipated to enclose the results of the radar data in the thesis, but numerous problems were encountered with the calibration of the ERS-2 data to sigma0 values. The Australian received and processed ERS-2 data did not comply with the ESA header convention and calibration could not be processed by conventional image processing tools (ESA BEST toolbox; ESA, 2005). After much discussion and trials with the Australian Centre for Remote Sensing (ACRES) (regarding problem analysis and changes to their Vexcel SAR Processor) and still no delivery of correct header files, the author had to exclude this data set from the study. The author hopes to include the ERS data set in the study in the future and report on results in a paper, but regrettably not in the thesis.

Acquisition Date	**DOY**	**Date**
1998 Data	168	17/06/1998
	203	22/07/1998
	238	26/08/1998
	273	30/09/1998
	308	04/11/1998
	343	09/12/1998
1999 Data	223	11/08/1999
	258	15/09/1999
	293	20/10/1999
	328	24/11/1999
	363	29/12/1999

Acquisition was also scheduled for 07/07/1999, but the Ground station reported an acquisition failure for that data set.

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	CROP98	SOW_D98	HARVST_D98	181NDVI	181NDVI STD_DEV	181-1MEAN	181-1STD_DEV	181-2MEAN	181-2STD_DEV	181-3MEAN	181-3STD_DEV	221NDVI	221NDVI STD_DEV
5- 6	Barley	19980522	19981129	0.28	0.08	5.52	0.80	8.45	1.15	15.26	2.26	0.61	0.04
6- 19	Barley	19980527	0	0.29	0.04	5.13	0.63	8.59	0.83	15.83	1.78	0.61	0.06
10- 8	Barley	19980602	19981209	0.26	0.05	6.93	0.89	11.22	1.31	19.20	1.53	0.43	0.10
10- 9	Barley	19980601	19981210	0.25	0.04	7.03	1.06	11.09	1.40	18.61	1.84	0.44	0.06
13- 7	Barley	19980511	0	0.51	0.05	4.92	0.50	6.91	0.71	21.64	1.71	0.77	0.06
17- 5	Barley	0	0	0.32	0.09	3.84	0.35	6.11	0.57	12.34	2.74	0.60	0.06
20- 28	Barley	19980518	0	0.44	0.07	3.29	0.39	6.15	0.82	16.18	3.08	0.65	0.07
20- 29	Barley	19980518	0	0.48	0.14	3.58	0.66	6.13	1.10	19.63	7.93	0.60	0.08
20- 30	Barley	19980519	0	0.42	0.07	3.22	0.70	6.59	1.17	16.35	3.71	0.64	0.07
27- 2	Barley	0	0	0.49	0.09	4.58	1.02	7.89	2.07	23.05	2.66	0.77	0.07
27- 18	Barley	0	0	0.41	0.14	3.75	0.89	7.03	2.12	17.96	6.54	0.67	0.06
27- 20	Barley	0	0	0.27	0.12	4.75	0.60	7.86	1.21	14.27	3.50	0.34	0.07
27- 21	Barley	0	0	0.76	0.07	4.23	0.29	4.74	0.95	36.36	4.14	0.60	0.06
27- 23	Barley	0	0	0.69	0.11	4.04	0.38	5.37	1.29	31.80	6.46	0.61	0.06
3- 1	Canola	19980501	0	0.54	0.09	3.30	0.50	5.35	0.83	18.45	3.28	0.77	0.04
3- 6	Canola	19980501	0	0.45	0.07	4.15	0.39	6.56	0.65	17.82	2.54	0.74	0.05
3- 10	Canola	19980501	0	0.41	0.10	3.80	0.33	6.26	0.75	15.59	3.64	0.66	0.08
5- 1	Canola	19980509	19981201	0.60	0.07	4.59	0.37	6.61	1.01	26.96	2.75	0.78	0.05
5- 2	Canola	19980509	19981201	0.67	0.05	3.94	0.55	5.13	0.74	26.32	3.97	0.79	0.06
5- 3	Canola	19980509	19981201	0.69	0.08	4.16	0.31	4.77	0.39	27.56	6.09	0.78	0.06
10- 4	Canola	19980512	19981207	0.34	0.07	5.28	0.77	8.66	1.02	18.01	2.02	0.62	0.08
10- 10	Canola	19980507	19981128	0.42	0.05	5.02	0.59	8.15	0.88	20.27	1.76	0.69	0.05
10- 14	Canola	19980506	19981203	0.41	0.06	4.96	0.56	7.57	0.85	18.43	1.80	0.68	0.09
10- 15	Canola	19980505	19981125	0.49	0.07	4.55	0.46	6.82	0.70	20.66	3.05	0.76	0.09
10- 18	Canola	19980514	19981204	0.41	0.15	3.55	0.50	6.49	1.15	17.15	6.48	0.61	0.07
13- 10	Canola	19980505	0	0.60	0.05	5.47	0.47	6.86	0.72	27.67	2.40	0.81	0.05
13- 11	Canola	19980504	0	0.60	0.07	5.22	0.52	6.78	0.94	27.53	3.40	0.79	0.05
14- 6	Canola	19980501	19981202	0.44	0.07	4.25	0.27	6.71	0.48	17.51	2.21	0.67	0.11
14- 21	Canola	19980505	19981123	0.42	0.11	4.59	1.12	7.36	2.18	17.85	2.82	0.67	0.09
14- 23	Canola	19980505	19981129	0.42	0.10	4.84	0.88	7.91	1.92	19.57	2.46	0.69	0.10
16- 5	Canola	19980506	0	0.42	0.07	5.39	0.70	7.37	0.74	18.55	3.00	0.62	0.10
16- 14	Canola	19960428	0	0.68	0.05	3.14	0.90	4.51	0.87	24.15	4.82	0.71	0.11
16- 16	Canola	19980424	0	0.72	0.06	4.23	0.29	4.91	0.65	30.87	3.63	0.82	0.04
16- 17	Canola	19980424	0	0.71	0.05	4.10	0.38	4.82	0.58	29.35	3.39	0.81	0.05
16- 18	Canola	19980424	0	0.70	0.04	4.20	0.41	5.00	0.47	29.76	3.32	0.83	0.05
17- 6	Canola	0	0	0.27	0.05	3.83	0.45	6.90	0.77	12.28	2.31	0.53	0.08
17- 11	Canola	0	0	0.38	0.05	3.97	0.22	6.07	0.38	13.70	1.56	0.64	0.07
20- 5	Canola	19980521	19981219	0.31	0.07	4.46	0.53	7.92	0.79	15.52	2.48	0.63	0.09
20- 15	Canola	19980502	19981124	0.45	0.08	5.94	1.16	9.84	1.81	25.99	2.33	0.77	0.07
20- 18	Canola	19980502	19981125	0.44	0.09	5.11	0.81	8.96	1.51	23.28	2.22	0.72	0.07
20- 31	Canola	19980507	0	0.39	0.05	2.96	0.26	5.61	0.50	12.91	1.67	0.62	0.07
22- 17	Canola	19980502	0	0.58	0.07	5.29	0.50	7.08	1.07	27.52	2.75	0.75	0.08
23- 2	Canola	19980523	0	0.31	0.08	4.33	0.42	7.99	1.14	15.42	2.05	0.54	0.06
27- 3	Canola	0	0	0.53	0.08	3.54	0.63	6.23	1.33	20.35	2.36	0.79	0.08
27- 7	Canola	0	0	0.45	0.09	4.43	0.72	8.01	1.54	21.59	3.29	0.74	0.07
3- 5	Chickpeas	19880515	0	0.29	0.11	5.65	1.13	9.21	1.72	16.64	1.81	0.40	0.10

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	CROP98	SOW_D98	HARVST_D98	181NDVI	181NDVI STD_DEV	181-1MEAN	181-1STD_DEV	181-2MEAN	181-2STD_DEV	181-3MEAN	181-3STD_DEV	221NDVI	221NDVI STD_DEV
3- 8	Chickpeas	19880515	0	0.36	0.14	4.31	1.14	7.10	1.76	15.51	3.56	0.43	0.09
3- 9	Chickpeas	19880515	0	0.35	0.12	3.82	0.66	6.70	1.22	14.33	3.39	0.41	0.09
10- 1	Chickpeas	19980611	19981231	0.22	0.07	6.14	0.83	9.60	1.13	15.34	1.97	0.26	0.06
13- 8	Chickpeas	19980603	0	0.23	0.04	6.71	0.90	10.75	1.22	17.26	1.24	0.29	0.04
13- 14	Chickpeas	19980519	0	0.29	0.07	4.25	0.41	6.97	0.67	13.04	2.04	0.37	0.07
14- 10	Chickpeas	19980617	19980104	0.27	0.03	3.36	0.39	6.31	0.65	11.19	1.54	0.30	0.04
14- 12	Chickpeas	19980619	19981207	0.25	0.03	4.46	0.26	7.58	0.39	12.66	0.94	0.27	0.04
14- 13	Chickpeas	19980624	19981228	0.27	0.08	4.32	0.57	7.47	0.81	13.21	3.06	0.27	0.08
14- 16	Chickpeas	19980527	19990107	0.22	0.05	5.26	0.22	8.45	0.40	13.56	1.47	0.30	0.06
3- 3	Lentils	19980531	0	0.26	0.04	5.07	0.63	8.57	0.79	14.65	1.06	0.32	0.05
3- 4	Lentils	19980531	0	0.27	0.04	4.54	0.44	8.23	0.57	14.43	1.30	0.34	0.04
3- 11	Lentils	19980531	0	0.26	0.06	5.19	0.36	8.87	0.64	15.44	2.03	0.32	0.07
13- 3	Lentils	19980601	0	0.24	0.10	7.24	1.15	11.23	1.84	18.24	1.48	0.31	0.11
13- 4	Lentils	19980602	0	0.24	0.08	6.45	0.77	10.25	1.16	17.08	2.01	0.31	0.07
13- 13	Lentils	19980521	0	0.25	0.03	6.48	0.38	9.77	0.52	16.34	1.03	0.39	0.04
14- 3	Lentils	19980506	19981223	0.24	0.04	4.58	0.31	7.48	0.37	12.33	1.07	0.29	0.04
14- 4	Lentils	19980507	19981224	0.24	0.06	4.63	0.44	7.51	0.60	12.49	1.02	0.29	0.06
14- 15	Lentils	19980627	19981229	0.28	0.12	3.94	0.55	6.85	0.73	12.91	4.42	0.29	0.11
3- 2	Wheat	19980531	0	0.47	0.11	3.86	0.79	6.09	1.28	17.46	3.02	0.73	0.05
3- 15	Wheat	19980501	0	0.60	0.11	3.16	0.50	4.55	0.77	19.90	6.47	0.76	0.05
3- 17	Wheat	19980501	0	0.59	0.07	2.42	0.47	3.98	0.63	15.84	2.93	0.80	0.06
3- 20	Wheat	19880515	0	0.62	0.07	3.34	0.47	4.56	0.82	19.87	3.21	0.80	0.07
3- 22	Wheat	19880515	0	0.49	0.06	3.28	0.36	5.50	0.63	16.43	1.32	0.74	0.08
5- 7	Wheat	19980514	19981207	0.67	0.07	3.31	0.59	4.28	0.82	22.02	3.20	0.78	0.07
5- 8	Wheat	19980515	19981208	0.60	0.07	3.44	0.36	4.73	0.64	19.51	2.03	0.77	0.06
6- 20	Wheat	19980515	0	0.53	0.04	3.87	0.37	5.80	0.64	19.12	1.35	0.82	0.03
10- 2	Wheat	19980528	19981221	0.31	0.05	3.49	0.45	6.59	0.60	12.64	1.28	0.48	0.04
10- 3	Wheat	19980519	19981216	0.34	0.03	5.53	0.68	8.80	0.85	18.11	1.59	0.64	0.05
10- 7	Wheat	19980516	19981215	0.43	0.05	4.25	0.58	7.48	0.98	18.87	1.96	0.73	0.10
10- 13	Wheat	19980521	19981211	0.38	0.06	4.27	0.40	6.91	0.63	15.71	1.99	0.70	0.06
10- 17	Wheat	19980516	19981219	0.49	0.11	4.01	0.46	6.11	0.92	19.14	5.96	0.73	0.05
10- 19	Wheat	19980515	19981219	0.49	0.10	3.91	0.49	6.02	0.99	18.06	3.30	0.70	0.06
13- 2	Wheat	19980512	0	0.51	0.07	4.38	0.79	6.53	1.03	20.21	2.42	0.73	0.09
13- 6	Wheat	19980513	0	0.48	0.10	4.62	0.78	6.83	1.32	20.34	4.44	0.72	0.06
13- 15	Wheat	19980507	0	0.62	0.10	3.78	0.66	4.98	1.12	22.35	4.64	0.78	0.07
13- 16	Wheat	19980506	0	0.66	0.08	3.49	0.69	4.62	0.93	23.80	5.87	0.70	0.12
14- 2	Wheat	19980521	19981217	0.34	0.05	3.98	0.30	6.61	0.51	13.51	1.51	0.54	0.05
14- 5	Wheat	19980515	19981215	0.38	0.06	4.13	0.36	6.74	0.54	15.31	1.93	0.66	0.06
14- 14	Wheat	19980509	19981211	0.54	0.05	3.82	0.38	5.45	0.64	18.80	1.83	0.77	0.05
14- 17	Wheat	19980512	19981204	0.41	0.10	4.78	1.07	7.38	1.49	17.86	1.73	0.67	0.07
14- 18	Wheat	19980512	19981209	0.40	0.02	5.53	0.45	8.30	0.48	19.76	1.17	0.72	0.04
14- 19	Wheat	19980512	19981209	0.44	0.10	4.67	1.09	7.37	1.58	19.00	2.57	0.67	0.09
14- 20	Wheat	19980512	19981210	0.43	0.04	4.84	0.59	7.30	0.89	18.62	1.96	0.71	0.08
16- 6	Wheat	19950516	0	0.40	0.07	4.55	0.73	6.63	0.84	15.78	2.80	0.66	0.06
16- 7	Wheat	19980514	0	0.42	0.06	3.96	0.69	5.92	0.74	14.61	2.39	0.69	0.08
16- 15	Wheat	19980430	0	0.67	0.07	3.59	0.44	4.84	0.83	25.38	3.32	0.79	0.06

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	CROP98	SOW_D98	HARVST_D98	181NDVI	181NDVI STD_DEV	181-1MEAN	181-1STD_DEV	181-2MEAN	181-2STD_DEV	181-3MEAN	181-3STD_DEV	221NDVI	221NDVI STD_DEV
16- 20	Wheat	19980430	0	0.63	0.06	3.21	0.36	4.77	0.70	21.93	2.64	0.76	0.05
20- 2	Wheat	19980530	19981222	0.36	0.12	3.69	0.59	6.70	1.10	14.78	4.29	0.56	0.06
20- 3	Wheat	19980604	19990101	0.29	0.06	3.66	0.34	6.51	0.54	12.03	2.02	0.53	0.08
20- 10	Wheat	19980601	19990112	0.35	0.07	2.47	0.51	5.11	0.55	10.91	3.07	0.57	0.05
20- 34	Wheat	19980510	0	0.35	0.09	4.02	0.62	8.24	1.14	17.61	2.73	0.56	0.09
22- 14	Wheat	19980512	0	0.50	0.06	4.26	0.30	6.19	0.81	18.83	1.88	0.69	0.06
27- 6	Wheat	0	0	0.53	0.09	5.14	1.10	7.44	1.58	24.67	2.67	0.66	0.07
27- 17	Wheat	0	0	0.39	0.17	4.05	0.92	6.31	1.42	15.73	6.15	0.46	0.11

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	221-1MEAN	221-1STD_DEV	221-2MEAN	221-2STD_DEV	221-3MEAN	221-3STD_DEV	240 NDVI	240 NDVI STD_DEV	240-1MEAN	240-1STD_DEV	240-2MEAN	240-2STD_DEV	240-3MEAN
5- 6	7.31	0.49	6.66	0.56	27.88	1.96	0.81	0.03	4.07	0.43	40.13	3.17	20.08
6- 19	7.77	0.59	7.35	0.98	31.29	3.08	0.81	0.04	4.72	0.93	47.00	3.24	21.11
10- 8	9.56	1.45	10.73	1.87	27.51	2.90	0.63	0.10	7.41	1.68	33.45	4.66	17.40
10- 9	9.17	1.25	10.17	1.32	26.73	2.77	0.63	0.07	7.20	1.17	32.45	3.15	17.72
13- 7	6.39	0.62	5.13	0.80	41.03	3.91	0.84	0.06	3.89	0.79	47.36	4.64	19.80
17- 5	7.48	0.65	6.53	1.10	26.62	3.46	0.72	0.05	4.99	0.81	31.04	2.43	17.04
20- 28	6.51	0.73	6.72	1.25	32.52	2.97	0.73	0.06	5.78	1.20	38.03	3.37	17.61
20- 29	6.91	1.07	7.38	1.20	30.08	4.33	0.65	0.06	7.01	1.04	33.86	4.02	14.97
20- 30	6.31	0.73	6.72	1.17	31.52	4.39	0.72	0.06	5.74	1.06	37.18	3.88	17.61
27- 2	6.64	0.85	5.22	1.34	42.82	5.19	0.82	0.08	4.25	1.05	47.88	7.34	20.43
27- 18	6.70	1.05	6.21	1.13	32.09	4.85	0.78	0.07	4.57	1.05	38.45	5.84	18.86
27- 20	9.96	0.80	11.20	1.11	23.32	2.10	0.57	0.09	8.24	1.18	31.26	4.50	15.76
27- 21	8.13	0.51	7.90	0.95	32.72	3.31	0.65	0.06	7.11	0.78	34.39	3.30	15.43
27- 23	7.86	0.61	7.52	0.91	32.37	4.96	0.61	0.07	7.61	0.78	32.48	4.76	14.58
3- 1	7.17	0.69	5.36	0.67	43.73	5.41	0.84	0.04	4.26	0.53	51.19	6.97	19.74
3- 6	7.50	0.44	5.93	0.75	40.82	4.69	0.84	0.04	4.04	0.70	49.41	5.08	19.56
3- 10	7.42	0.54	6.73	1.04	33.97	4.89	0.81	0.05	4.53	0.89	46.32	5.77	19.77
5- 1	7.56	0.22	5.42	0.86	47.29	5.37	0.83	0.05	4.38	0.70	52.11	7.12	18.18
5- 2	7.41	0.49	5.03	0.62	47.05	7.36	0.84	0.08	4.03	0.67	52.60	9.70	18.95
5- 3	7.57	0.38	5.38	0.88	45.98	6.07	0.82	0.05	4.77	0.82	50.31	6.64	18.19
10- 4	7.85	0.90	7.78	1.30	34.04	4.07	0.80	0.06	5.05	1.10	47.36	6.27	20.26
10- 10	7.55	0.53	6.96	0.75	38.56	3.81	0.82	0.05	4.81	0.70	51.33	5.73	20.52
10- 14	7.80	0.78	6.82	1.23	37.18	6.16	0.81	0.04	4.91	0.77	48.88	6.03	20.22
10- 15	7.31	0.65	5.62	1.52	44.54	6.34	0.82	0.09	4.93	1.83	52.10	6.85	19.37
10- 18	6.99	0.75	7.34	1.01	31.26	4.37	0.79	0.04	5.14	0.67	45.65	5.55	19.93
13- 10	7.07	0.36	5.07	0.65	50.38	5.05	0.86	0.04	3.98	0.59	56.84	5.47	20.61
13- 11	6.45	0.68	5.07	0.85	45.65	4.40	0.85	0.04	3.81	0.73	49.36	4.09	19.78
14- 6	7.55	0.54	6.81	1.34	37.04	6.83	0.81	0.07	4.95	1.03	49.98	8.22	20.20
14- 21	8.20	1.12	7.00	1.68	37.70	7.48	0.79	0.10	4.58	1.10	44.68	9.69	18.72
14- 23	8.31	0.85	7.03	1.59	40.17	7.31	0.81	0.08	4.59	1.14	47.04	8.47	19.08
16- 5	9.52	1.16	8.15	1.61	35.92	4.03	0.75	0.10	6.18	1.65	46.05	6.89	17.59
16- 14	6.83	0.76	5.64	1.04	37.15	10.28	0.69	0.10	6.08	0.59	37.04	10.96	14.43
16- 16	6.53	0.49	4.40	0.59	46.58	4.18	0.72	0.03	7.17	0.86	44.65	4.21	15.26
16- 17	6.90	0.55	4.64	0.71	47.28	4.78	0.72	0.03	7.08	0.71	45.20	4.76	15.58
16- 18	6.92	0.39	4.43	0.74	49.13	4.97	0.73	0.03	6.90	0.65	46.37	5.00	15.14
17- 6	8.38	0.70	7.95	1.36	26.11	3.49	0.77	0.06	4.60	1.21	35.94	2.80	19.22
17- 11	8.48	0.49	7.10	1.18	32.56	3.35	0.79	0.07	5.38	1.41	46.78	4.91	20.23
20- 5	8.26	0.70	7.98	1.36	36.44	5.33	0.80	0.09	4.98	1.35	49.73	8.45	19.97
20- 15	6.51	0.86	5.53	1.12	44.43	6.45	0.82	0.08	4.94	1.21	52.56	8.10	17.63
20- 18	6.95	0.81	6.59	1.36	42.85	5.32	0.80	0.07	5.48	1.24	51.67	7.49	18.37
20- 31	7.07	0.49	7.16	1.06	31.21	3.28	0.75	0.08	5.37	1.24	38.48	4.21	16.43
22- 17	7.73	0.51	6.11	1.13	44.41	6.43	0.79	0.08	5.14	1.17	45.61	6.17	15.82
23- 2	9.30	0.98	9.83	1.51	33.55	2.31	0.75	0.06	5.93	0.74	43.57	5.50	17.98
27- 3	5.17	0.82	3.94	1.32	34.71	3.36	0.82	0.07	3.47	1.19	37.99	4.15	20.21
27- 7	5.67	0.73	4.87	1.23	33.93	3.82	0.81	0.06	3.66	0.99	36.55	4.64	19.37
3- 5	8.37	1.16	9.67	1.69	22.78	3.04	0.52	0.09	8.49	1.62	27.35	2.82	14.68

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	221-1MEAN	221-1STD_DEV	221-2MEAN	221-2STD_DEV	221-3MEAN	221-3STD_DEV	240 NDVI	240 NDVI STD_DEV	240-1MEAN	240-1STD_DEV	240-2MEAN	240-2STD_DEV	240-3MEAN
3- 8	8.59	1.46	9.62	1.84	24.50	3.25	0.55	0.06	8.58	1.62	30.11	3.04	15.04
3- 9	8.07	0.97	9.42	1.48	23.01	2.81	0.53	0.07	8.82	1.43	28.68	2.17	14.37
10- 1	9.85	0.82	11.33	0.88	19.75	2.06	0.34	0.07	10.78	1.00	22.21	2.06	9.23
13- 8	9.54	0.77	11.38	0.78	20.91	1.26	0.35	0.05	11.21	1.02	23.37	1.53	9.12
13- 14	8.46	0.92	9.67	1.32	21.24	2.50	0.50	0.07	8.22	1.35	25.15	2.17	14.20
14- 10	8.37	0.49	10.27	0.74	19.22	2.01	0.35	0.03	10.04	0.65	21.22	1.84	9.24
14- 12	9.04	0.62	10.89	0.71	19.26	1.70	0.32	0.03	10.63	0.59	20.87	1.43	8.10
14- 13	8.86	0.97	10.85	0.98	19.33	3.50	0.31	0.07	10.73	1.03	20.80	3.29	7.55
14- 16	9.59	0.66	10.85	0.78	20.43	2.54	0.41	0.06	9.34	0.75	22.56	2.83	11.29
3- 3	8.86	0.87	10.63	1.02	20.65	1.80	0.47	0.06	9.16	1.12	25.56	1.61	13.67
3- 4	8.03	0.51	10.00	0.70	20.56	1.97	0.51	0.05	8.25	0.78	26.00	1.87	15.05
3- 11	8.69	0.60	10.74	0.89	21.25	3.14	0.45	0.08	9.54	1.12	25.82	3.72	13.11
13- 3	9.68	1.08	11.09	1.70	21.56	3.40	0.43	0.10	9.86	1.69	25.42	3.29	12.28
13- 4	9.26	0.79	11.06	0.96	21.27	2.23	0.42	0.07	9.94	1.11	24.86	2.13	11.59
13- 13	9.28	0.62	10.02	0.64	23.09	1.58	0.61	0.04	7.33	0.73	30.95	1.99	17.57
14- 3	8.10	0.50	9.70	0.58	18.01	1.16	0.37	0.06	9.13	0.79	19.96	1.39	10.04
14- 4	8.17	0.53	9.79	0.62	18.13	1.70	0.36	0.07	9.30	0.87	19.98	1.86	9.71
14- 15	9.42	1.03	10.75	1.39	20.37	4.75	0.31	0.11	10.45	1.24	20.55	4.91	7.14
3- 2	5.61	0.83	4.96	1.08	32.48	3.23	0.80	0.05	4.00	1.03	36.45	4.13	19.49
3- 15	5.22	0.61	4.48	0.67	34.47	4.26	0.83	0.07	3.31	1.13	37.79	4.83	20.08
3- 17	4.18	0.84	3.53	1.01	31.98	2.84	0.85	0.05	2.96	0.74	40.08	5.10	20.55
3- 20	5.16	1.01	4.26	1.33	39.14	4.06	0.86	0.07	2.88	1.34	41.80	4.65	20.74
3- 22	4.92	0.86	4.51	1.30	31.92	3.12	0.85	0.09	3.30	1.49	43.48	5.09	20.65
5- 7	4.83	1.01	3.86	1.20	32.95	2.34	0.83	0.08	3.46	1.38	40.21	3.65	19.48
5- 8	5.55	0.87	4.36	0.99	33.76	3.09	0.84	0.04	3.29	0.84	38.73	3.68	19.37
6- 20	5.54	0.54	4.02	0.78	42.03	1.83	0.88	0.04	3.11	0.84	50.24	2.71	21.67
10- 2	7.17	0.54	8.22	0.68	23.98	1.56	0.74	0.05	5.02	0.54	34.64	3.42	19.61
10- 3	6.95	0.85	6.95	0.94	32.07	2.05	0.81	0.05	3.90	1.19	38.86	2.19	20.57
10- 7	5.69	1.26	5.26	1.58	34.75	3.99	0.86	0.08	2.96	1.26	41.43	4.84	21.28
10- 13	5.63	0.70	5.38	0.97	31.06	2.91	0.84	0.06	3.31	1.02	38.72	3.65	20.56
10- 17	5.44	0.67	4.96	0.90	32.87	4.69	0.81	0.05	3.68	1.05	36.37	4.67	19.87
10- 19	5.69	1.00	5.39	1.18	31.56	2.63	0.80	0.05	3.89	0.96	36.82	5.31	19.78
13- 2	5.67	1.14	5.00	1.23	33.74	3.90	0.83	0.10	3.43	1.54	39.73	5.01	19.53
13- 6	5.82	0.63	5.33	0.91	34.18	4.60	0.82	0.07	3.55	1.00	38.52	5.63	19.60
13- 15	5.43	0.92	4.64	1.44	38.35	5.09	0.84	0.08	3.51	1.59	41.73	6.29	20.19
13- 16	5.99	1.40	5.59	1.83	33.17	6.61	0.75	0.12	4.70	1.96	35.77	7.45	18.06
14- 2	6.83	0.63	7.22	0.81	24.48	2.01	0.74	0.05	5.14	0.98	34.79	3.28	18.46
14- 5	5.89	0.62	5.75	0.88	29.02	2.50	0.82	0.07	3.71	0.96	38.77	4.00	19.85
14- 14	5.15	0.67	4.14	0.75	32.50	3.46	0.85	0.05	2.93	0.75	36.83	4.31	20.22
14- 17	6.59	0.94	5.82	1.14	30.71	4.09	0.78	0.09	4.04	1.10	35.78	5.94	18.31
14- 18	6.46	0.76	5.53	0.96	34.32	1.73	0.84	0.03	3.42	0.60	40.95	2.11	20.11
14- 19	6.48	1.10	5.95	1.63	30.89	4.35	0.76	0.12	4.29	1.65	34.74	6.48	18.81
14- 20	6.20	1.35	5.42	1.97	32.86	2.11	0.83	0.08	3.35	1.85	37.37	2.64	20.32
16- 6	7.09	0.82	6.00	1.01	30.17	2.79	0.76	0.06	4.99	0.89	38.96	4.61	18.25
16- 7	6.52	0.97	5.37	1.23	29.77	2.86	0.78	0.07	4.40	0.96	37.82	4.22	18.20
16- 15	5.74	0.66	4.23	1.07	37.57	4.05	0.83	0.08	3.34	1.47	36.78	4.31	19.87

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	221-1MEAN	221-1STD_DEV	221-2MEAN	221-2STD_DEV	221-3MEAN	221-3STD_DEV	240 NDVI	240 NDVI STD_DEV	240-1MEAN	240-1STD_DEV	240-2MEAN	240-2STD_DEV	240-3MEAN
16- 20	5.79	0.48	4.49	0.88	34.50	2.55	0.83	0.04	3.04	0.70	33.35	1.93	18.37
20- 2	6.44	0.75	7.32	1.01	26.35	2.72	0.76	0.07	4.62	1.04	35.04	5.44	18.77
20- 3	6.78	0.70	7.28	1.10	23.88	2.49	0.71	0.08	4.96	1.09	30.72	8.05	18.70
20- 10	5.99	0.58	6.64	0.82	24.91	2.07	0.78	0.07	4.03	0.87	34.87	3.38	19.76
20- 34	6.58	0.65	8.06	1.55	29.68	3.42	0.69	0.06	6.30	1.31	35.57	2.08	17.45
22- 14	6.80	0.79	6.01	1.10	34.12	3.54	0.81	0.04	3.82	1.00	37.82	3.32	0.00
27- 6	7.58	0.78	6.81	1.19	34.38	3.81	0.75	0.06	5.55	0.92	40.22	5.44	18.53
27- 17	8.21	1.43	8.01	1.73	22.31	4.92	0.62	0.07	6.53	1.11	28.65	4.49	16.14

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	240-3STD_DEV	251NDVI	251NDVI STD_DEV	251-1MEAN	251-1STD_DEV	251-2MEAN	251-2STD_DEV	251-3MEAN	251-3STD_DEV	287NDVI	287NDVI STD_DEV	287-1MEAN
5- 6	0.79	0.80	0.03	6.20	0.43	4.15	0.55	39.51	4.43	0.64	0.06	5.19
6- 19	0.94	0.84	0.04	6.73	0.65	4.03	1.01	49.74	4.98	0.79	0.05	4.73
10- 8	1.80	0.70	0.07	7.63	0.94	6.43	1.25	37.22	4.89	0.75	0.05	5.04
10- 9	1.82	0.71	0.07	7.47	0.65	6.20	1.23	37.59	3.73	0.76	0.07	4.93
13- 7	2.03	0.79	0.08	7.62	2.07	5.54	2.09	49.40	5.49	0.77	0.05	5.12
17- 5	1.11	0.68	0.04	6.60	0.50	5.54	0.82	29.89	2.25	0.61	0.06	5.70
20- 28	1.73	0.70	0.07	6.89	0.70	6.26	1.24	37.33	3.81	0.55	0.07	5.99
20- 29	1.98	0.60	0.08	8.10	1.06	8.00	1.35	32.89	4.46	0.51	0.06	6.80
20- 30	1.76	0.70	0.07	6.65	0.71	6.16	1.26	36.71	3.97	0.57	0.06	5.71
27- 2	2.21	0.82	0.09	6.25	0.49	4.42	1.30	48.45	8.13	0.70	0.11	5.39
27- 18	2.30	0.75	0.09	6.43	1.25	5.21	1.70	39.16	5.91	0.61	0.07	5.51
27- 20	2.11	0.63	0.08	7.32	1.70	6.30	1.99	28.86	9.03	0.64	0.10	7.50
27- 21	1.82	0.62	0.07	7.06	1.81	6.64	2.40	28.34	8.22	0.53	0.11	6.53
27- 23	1.84	0.58	0.07	6.44	1.68	6.21	2.45	23.44	6.53	0.51	0.09	7.42
3- 1	1.30	0.79	0.05	6.83	0.68	5.10	0.68	45.89	6.93	0.73	0.05	6.41
3- 6	1.20	0.78	0.05	7.61	0.59	5.69	0.85	48.48	4.72	0.73	0.03	6.57
3- 10	1.10	0.79	0.04	7.19	0.67	5.31	0.74	47.39	4.93	0.73	0.05	6.41
5- 1	1.30	0.73	0.05	9.19	1.31	7.59	1.36	49.59	5.67	0.68	0.07	6.41
5- 2	1.92	0.76	0.08	7.91	0.65	6.19	0.59	48.65	8.68	0.71	0.10	6.36
5- 3	0.94	0.73	0.04	7.49	1.61	6.06	1.61	39.51	10.25	0.67	0.08	6.39
10- 4	1.37	0.81	0.05	6.97	0.73	4.95	0.98	49.89	6.11	0.76	0.05	6.44
10- 10	1.11	0.82	0.04	6.70	0.49	4.83	0.77	51.57	5.17	0.78	0.04	6.24
10- 14	0.78	0.81	0.03	7.43	0.44	5.23	0.47	51.65	4.94	0.76	0.03	6.82
10- 15	1.90	0.77	0.08	7.97	0.85	6.33	1.61	52.37	5.78	0.75	0.04	6.97
10- 18	1.77	0.80	0.07	6.96	0.61	5.25	1.22	49.56	7.01	0.76	0.10	6.37
13- 10	1.23	0.82	0.05	7.14	0.87	5.07	1.09	55.04	5.06	0.78	0.05	6.58
13- 11	1.29	0.79	0.05	7.32	0.83	5.40	0.95	48.32	5.91	0.74	0.04	6.26
14- 6	1.38	0.81	0.06	7.34	0.93	5.31	1.16	52.55	6.14	0.79	0.03	6.58
14- 21	2.20	0.75	0.09	8.00	1.10	6.26	1.39	47.03	8.91	0.72	0.09	6.76
14- 23	1.84	0.76	0.07	7.70	0.83	5.97	1.06	47.93	10.10	0.74	0.09	6.78
16- 5	2.30	0.70	0.09	8.25	0.96	6.86	1.44	41.37	5.46	0.57	0.10	7.95
16- 14	1.79	0.58	0.07	7.83	2.11	7.56	1.90	30.08	11.11	0.56	0.09	6.94
16- 16	1.18	0.61	0.05	10.41	1.57	9.69	1.73	41.13	8.01	0.63	0.04	7.55
16- 17	0.77	0.62	0.03	11.40	1.03	10.78	1.14	47.15	3.81	0.61	0.04	7.55
16- 18	0.57	0.61	0.02	11.67	1.11	11.42	1.15	47.22	4.31	0.61	0.04	7.52
17- 6	1.58	0.77	0.06	7.63	1.39	5.26	1.56	41.30	4.14	0.73	0.06	5.16
17- 11	0.73	0.81	0.03	7.54	0.20	5.07	0.71	49.62	3.21	0.70	0.05	6.33
20- 5	2.49	0.80	0.10	6.70	0.65	5.02	1.65	49.08	7.91	0.75	0.09	6.51
20- 15	1.56	0.71	0.06	9.23	1.01	8.11	1.06	49.05	7.40	0.71	0.07	7.05
20- 18	1.18	0.73	0.05	8.19	0.67	7.22	0.96	48.82	4.61	0.70	0.07	6.88
20- 31	1.12	0.66	0.04	7.61	0.37	7.33	0.75	36.26	2.86	0.63	0.04	6.50
22- 17	1.11	0.63	0.04	9.67	2.53	8.49	2.54	38.75	11.94	0.64	0.04	6.98
23- 2	1.29	0.72	0.05	7.59	0.43	6.72	0.88	42.60	3.91	0.59	0.07	7.65
27- 3	1.61	0.81	0.06	4.98	0.83	3.83	1.15	37.75	3.85	0.68	0.05	5.14
27- 7	1.93	0.77	0.08	5.50	1.02	4.56	1.45	37.56	4.80	0.64	0.07	5.60
3- 5	1.66	0.59	0.07	7.95	1.01	7.92	1.35	30.95	2.86	0.79	0.06	5.86

FULL_ID	240-3STD_DEV	251NDVI	251NDVI STD_DEV	251-1MEAN	251-1STD_DEV	251-2MEAN	251-2STD_DEV	251-3MEAN	251-3STD_DEV	287NDVI	287NDVI STD_DEV	287-1MEAN
3- 8	1.34	0.60	0.05	8.96	1.48	8.41	1.50	34.41	4.00	0.75	0.11	6.62
3- 9	1.18	0.57	0.05	8.68	1.59	8.23	1.66	31.07	6.00	0.73	0.08	6.99
10- 1	1.57	0.37	0.06	10.45	1.25	11.12	1.47	24.43	2.75	0.65	0.05	7.75
13- 8	1.22	0.36	0.05	9.87	0.69	11.36	0.91	24.67	1.45	0.69	0.05	6.73
13- 14	1.59	0.57	0.06	8.06	0.79	7.78	1.30	28.65	1.97	0.79	0.06	5.66
14- 10	0.68	0.37	0.03	9.46	1.42	10.78	1.59	23.69	3.36	0.68	0.05	6.53
14- 12	0.79	0.32	0.03	10.09	0.69	11.54	0.82	22.88	1.04	0.57	0.05	7.56
14- 13	1.49	0.30	0.06	9.95	0.92	11.71	1.10	22.23	2.59	0.50	0.05	7.95
14- 16	1.13	0.45	0.05	9.15	0.78	9.24	0.88	24.83	2.59	0.72	0.05	6.21
3- 3	1.63	0.55	0.07	8.57	0.93	8.59	1.37	29.75	2.84	0.76	0.05	6.02
3- 4	1.31	0.60	0.05	7.37	0.50	7.36	0.84	30.25	2.45	0.78	0.06	5.80
3- 11	1.91	0.52	0.08	8.52	0.74	8.96	1.17	29.44	3.56	0.76	0.05	6.11
13- 3	1.64	0.49	0.07	8.18	2.24	7.87	2.16	23.96	7.77	0.76	0.06	6.46
13- 4	1.53	0.46	0.06	8.96	0.72	9.69	1.10	26.83	1.92	0.77	0.07	6.56
13- 13	1.12	0.70	0.04	8.09	0.46	6.37	0.79	37.49	3.42	0.84	0.04	6.41
14- 3	1.40	0.40	0.06	9.22	0.55	9.82	0.97	23.26	1.18	0.73	0.06	6.64
14- 4	1.84	0.39	0.07	9.21	0.63	9.94	1.07	22.92	1.89	0.71	0.09	6.74
14- 15	2.38	0.29	0.10	10.17	1.09	11.66	1.53	21.54	4.43	0.42	0.08	8.55
3- 2	1.31	0.78	0.05	5.12	0.69	4.15	0.93	34.76	3.98	0.68	0.05	4.83
3- 15	1.99	0.80	0.08	4.69	1.15	3.83	1.33	37.02	4.45	0.76	0.10	4.35
3- 17	1.61	0.82	0.06	4.47	0.73	3.39	0.92	36.71	4.41	0.74	0.06	4.49
3- 20	1.97	0.83	0.08	4.41	0.97	3.48	1.26	39.73	4.44	0.78	0.08	4.02
3- 22	1.94	0.83	0.08	5.01	1.15	3.83	1.57	41.96	4.34	0.80	0.05	3.90
5- 7	1.63	0.78	0.07	5.43	0.89	4.23	1.19	35.05	2.24	0.56	0.07	5.76
5- 8	0.95	0.77	0.04	5.96	1.01	4.48	0.89	36.03	2.75	0.62	0.07	5.24
6- 20	1.05	0.87	0.04	4.72	0.64	3.25	0.97	47.40	2.53	0.78	0.05	4.03
10- 2	0.87	0.78	0.03	6.19	0.36	4.65	0.42	39.94	3.82	0.83	0.05	4.55
10- 3	1.15	0.82	0.05	4.88	0.77	3.73	1.10	39.42	1.73	0.78	0.07	3.92
10- 7	1.41	0.85	0.06	4.43	0.78	3.29	0.99	43.18	3.77	0.75	0.14	5.40
10- 13	1.38	0.82	0.06	4.81	0.83	3.66	1.04	39.21	3.73	0.79	0.07	3.97
10- 17	1.42	0.79	0.06	4.58	1.06	3.89	1.21	35.09	4.50	0.74	0.09	3.88
10- 19	1.39	0.79	0.06	5.06	1.06	4.21	1.20	37.51	6.26	0.78	0.05	3.96
13- 2	2.77	0.78	0.11	5.84	1.82	4.81	2.17	41.32	5.20	0.72	0.10	4.78
13- 6	1.82	0.78	0.07	4.92	0.92	3.89	1.05	34.76	8.77	0.71	0.06	4.47
13- 15	1.96	0.81	0.08	5.17	1.23	4.09	1.53	40.33	6.51	0.73	0.08	4.26
13- 16	2.86	0.72	0.11	6.03	1.69	5.42	2.06	35.48	7.24	0.66	0.10	5.25
14- 2	1.40	0.74	0.06	6.49	0.98	5.32	1.30	36.12	3.04	0.74	0.07	4.44
14- 5	2.17	0.79	0.09	5.89	2.77	4.54	2.69	39.71	6.83	0.78	0.07	4.34
14- 14	1.33	0.81	0.05	5.23	1.20	3.76	1.27	36.67	4.53	0.72	0.06	4.37
14- 17	2.26	0.73	0.09	6.50	1.49	5.27	1.67	35.42	6.16	0.63	0.07	5.17
14- 18	1.70	0.80	0.07	5.43	1.11	4.00	1.35	38.29	4.34	0.69	0.04	4.78
14- 19	3.06	0.75	0.12	5.09	0.65	3.91	0.91	31.82	8.79	0.61	0.09	5.40
14- 20	1.79	0.81	0.07	5.10	0.99	3.70	1.30	37.35	3.30	0.68	0.07	4.85
16- 6	1.56	0.73	0.06	7.25	0.76	5.89	0.91	39.23	4.53	0.54	0.05	6.53
16- 7	1.76	0.73	0.07	6.65	0.83	5.34	1.03	35.16	3.55	0.53	0.05	6.57
16- 15	2.38	0.79	0.10	4.98	1.44	3.95	1.83	36.41	5.48	0.65	0.08	5.10

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	240-3STD_DEV	251NDVI	251NDVI STD_DEV	251-1MEAN	251-1STD_DEV	251-2MEAN	251-2STD_DEV	251-3MEAN	251-3STD_DEV	287NDVI	287NDVI STD_DEV	287-1MEAN
16- 20	1.82	0.73	0.07	6.81	2.36	5.62	2.28	36.24	3.66	0.63	0.04	5.04
20- 2	2.24	0.75	0.09	5.61	0.77	4.82	1.28	35.78	5.30	0.66	0.09	4.91
20- 3	1.53	0.75	0.06	5.67	0.91	4.69	0.85	34.40	7.90	0.67	0.04	4.93
20- 10	1.07	0.79	0.04	5.29	0.51	4.24	0.68	37.43	2.68	0.70	0.06	4.57
20- 34	1.55	0.70	0.06	6.20	0.93	6.14	1.32	35.22	2.20	0.60	0.04	5.83
22- 14	0.00	0.00	0.00	8.75	3.51	7.89	3.20	36.94	9.29	0.64	0.06	5.05
27- 6	1.75	0.74	0.07	7.11	0.66	5.86	1.03	41.52	5.96	0.66	0.08	6.50
27- 17	2.55	0.65	0.10	7.83	0.93	6.55	1.55	31.91	5.65	0.58	0.13	6.44

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	287-1STD_DEV	287-2MEAN	287-2STD_DEV	287-3MEAN	287-3STD_DEV	320NDVI	320NDVI STD_DEV	320-1MEAN	320-1STD_DEV	320-2MEAN	320-2STD_DEV	320-3MEAN	320-3STD_DEV
5- 6	0.80	5.40	1.10	24.95	1.56	0.19	0.02	13.76	0.87	17.25	1.06	25.53	1.13
6- 19	0.57	3.90	0.94	34.41	1.43	0.25	0.03	10.47	1.49	14.05	2.01	23.37	2.40
10- 8	1.00	4.69	1.24	33.78	2.63	0.37	0.03	9.11	0.76	11.47	1.01	25.43	1.27
10- 9	0.66	4.56	1.16	34.29	2.90	0.38	0.04	9.06	0.75	11.39	0.96	25.60	1.68
13- 7	0.55	4.34	0.73	33.75	2.64	0.26	0.03	9.78	0.67	13.05	0.82	22.53	1.52
17- 5	0.87	5.83	1.59	24.68	3.85	0.29	0.04	10.60	0.69	13.15	1.30	23.65	1.52
20- 28	0.64	7.34	1.24	25.68	1.65	0.20	0.02	11.82	0.88	15.92	1.26	24.30	1.65
20- 29	0.81	8.24	1.19	25.47	1.88	0.23	0.05	11.08	1.54	14.57	2.06	23.58	1.89
20- 30	0.65	7.06	1.12	25.81	1.71	0.23	0.04	10.64	1.22	14.60	1.66	23.34	1.71
27- 2	0.73	5.41	1.52	31.67	4.41	0.25	0.04	10.30	0.86	14.01	1.59	23.72	1.79
27- 18	0.79	6.25	1.27	26.46	3.40	0.23	0.04	11.35	1.68	14.96	2.41	23.89	2.90
27- 20	0.65	7.34	1.50	34.88	4.42	0.32	0.04	11.79	0.69	14.35	0.85	28.27	2.13
27- 21	0.99	7.91	1.90	25.97	2.78	0.28	0.03	10.51	0.78	13.49	1.11	24.34	1.93
27- 23	0.31	8.65	1.01	27.28	4.14	0.25	0.03	11.02	0.96	13.90	1.33	23.48	1.85
3- 1	0.39	5.75	0.53	38.60	4.70	0.32	0.03	10.62	0.62	13.70	0.83	27.11	1.75
3- 6	0.38	5.80	0.44	38.07	3.27	0.28	0.04	11.86	1.22	14.99	1.49	27.23	1.34
3- 10	0.38	5.78	0.80	38.55	3.43	0.36	0.04	10.61	0.69	13.45	0.93	28.86	2.00
5- 1	0.37	6.28	0.68	35.00	5.51	0.23	0.02	11.80	0.60	15.47	0.96	25.09	1.00
5- 2	0.35	5.78	1.03	36.83	6.41	0.26	0.03	11.30	0.82	14.56	1.34	24.87	1.60
5- 3	0.37	6.31	0.83	33.21	5.25	0.25	0.02	11.64	1.02	14.71	0.92	24.62	1.47
10- 4	0.74	5.59	0.92	43.31	4.73	0.39	0.04	10.37	0.82	13.05	1.08	29.99	2.40
10- 10	0.33	5.27	0.55	43.36	4.04	0.41	0.03	9.68	0.50	12.20	0.59	29.55	2.27
10- 14	0.52	5.93	0.55	44.63	3.43	0.39	0.04	10.75	0.65	13.33	0.60	30.79	2.23
10- 15	0.49	6.15	0.76	44.27	2.77	0.34	0.07	10.81	1.18	13.63	1.48	27.93	2.17
10- 18	0.51	5.73	1.40	44.18	7.01	0.44	0.06	10.00	0.67	12.29	1.06	32.13	3.28
13- 10	0.36	5.43	0.85	45.99	4.67	0.35	0.05	10.89	0.84	13.77	0.80	29.08	2.44
13- 11	0.57	5.62	0.86	39.23	3.26	0.28	0.03	10.54	0.81	13.38	0.88	24.26	1.40
14- 6	0.29	5.11	0.33	46.38	3.66	0.44	0.04	10.31	0.37	12.60	0.70	32.54	1.93
14- 21	0.61	5.83	0.89	38.49	7.14	0.31	0.04	11.05	1.07	13.94	1.51	26.94	2.25
14- 23	0.51	5.71	1.05	41.06	7.09	0.35	0.04	10.68	0.71	13.53	1.10	28.31	2.45
16- 5	1.35	8.20	1.96	30.49	2.53	0.32	0.05	12.50	1.48	14.27	1.74	27.82	1.63
16- 14	0.68	7.28	0.75	27.54	5.68	0.28	0.07	10.46	1.93	14.22	3.20	25.14	2.43
16- 16	0.65	7.25	0.55	32.20	3.40	0.17	0.03	16.88	2.59	21.96	3.13	31.40	2.85
16- 17	0.62	7.27	0.54	30.79	3.35	0.16	0.03	17.32	2.53	22.00	2.98	31.10	2.59
16- 18	0.65	7.20	0.43	30.52	3.52	0.18	0.03	15.25	3.04	20.16	3.25	29.01	3.20
17- 6	0.50	4.66	0.92	30.39	2.87	0.23	0.04	12.26	1.47	16.78	2.03	27.13	2.35
17- 11	0.34	6.02	0.55	35.05	5.37	0.38	0.04	10.17	0.54	11.92	0.56	26.70	3.01
20- 5	0.63	5.67	1.22	42.34	6.96	0.36	0.04	10.47	0.53	13.14	0.75	28.42	2.71
20- 15	0.59	6.45	1.00	39.09	4.78	0.23	0.05	12.03	1.40	16.27	1.97	26.24	2.03
20- 18	0.52	6.55	1.23	38.63	4.33	0.23	0.04	12.98	1.56	18.09	2.31	29.28	2.12
20- 31	0.39	6.80	0.65	30.04	1.96	0.21	0.03	12.69	1.05	17.45	1.46	27.00	1.64
22- 17	0.43	7.50	0.82	34.79	1.91	0.23	0.02	12.34	0.56	16.24	0.97	26.05	1.01
23- 2	0.40	8.27	0.72	32.99	4.50	0.20	0.02	13.83	0.86	18.69	1.59	28.48	1.49
27- 3	0.46	5.13	0.74	27.70	1.72	0.25	0.03	9.55	0.76	12.68	1.20	21.11	2.00
27- 7	0.60	6.07	1.12	27.77	2.45	0.22	0.04	11.36	1.60	15.21	2.19	24.06	2.18
3- 5	0.56	4.60	0.75	42.51	6.16	0.65	0.11	8.31	0.88	8.53	1.73	42.94	6.81

FULL_ID	287-1STD_DEV	287-2MEAN	287-2STD_DEV	287-3MEAN	287-3STD_DEV	320NDVI	320NDVI STD_DEV	320-1MEAN	320-1STD_DEV	320-2MEAN	320-2STD_DEV	320-3MEAN	320-3STD_DEV
3- 8	0.61	5.47	1.09	41.34	8.40	0.56	0.12	9.49	0.84	9.99	1.68	37.25	7.38
3- 9	0.61	5.89	1.01	40.26	6.82	0.53	0.14	9.71	0.99	10.56	2.13	35.90	6.78
10- 1	0.67	6.92	0.73	34.03	3.18	0.50	0.08	10.04	1.09	10.87	1.55	33.09	4.19
13- 8	0.64	6.21	0.81	34.53	2.22	0.68	0.06	8.26	0.74	8.02	1.08	43.40	3.12
13- 14	0.48	4.72	0.83	41.48	4.14	0.64	0.08	8.01	0.65	8.16	1.18	38.50	4.47
14- 10	0.43	6.29	0.87	33.20	2.17	0.67	0.05	8.18	0.79	8.12	1.19	41.11	2.79
14- 12	0.42	7.76	0.72	28.99	1.68	0.64	0.03	8.82	0.49	8.74	0.57	40.88	1.73
14- 13	0.70	8.68	0.97	26.78	2.31	0.59	0.07	9.42	1.25	9.85	1.81	37.80	3.18
14- 16	0.38	5.55	0.74	34.49	2.33	0.64	0.09	8.26	0.92	8.28	1.97	38.42	4.55
3- 3	0.50	4.99	0.86	38.73	3.65	0.34	0.03	10.19	0.80	12.91	0.79	26.65	1.82
3- 4	0.63	4.70	1.22	39.16	3.31	0.32	0.03	9.31	0.56	12.31	0.55	24.59	1.81
3- 11	0.46	5.07	0.78	38.47	3.42	0.36	0.03	10.05	0.85	12.62	0.77	27.15	1.75
13- 3	0.50	5.13	0.91	39.93	4.54	0.46	0.05	10.48	0.65	11.98	0.83	32.51	3.50
13- 4	0.56	5.24	1.06	42.02	6.54	0.45	0.06	10.89	1.23	12.35	1.20	33.99	5.96
13- 13	0.38	4.61	0.87	56.19	4.66	0.59	0.05	10.92	0.55	11.05	0.72	43.60	4.57
14- 3	0.52	5.49	0.86	37.18	3.35	0.68	0.05	9.23	0.49	8.35	0.79	44.59	4.01
14- 4	0.56	5.64	1.10	34.81	5.04	0.65	0.07	9.32	0.54	8.70	0.99	42.78	5.29
14- 15	0.92	9.78	1.32	24.08	2.17	0.40	0.08	11.51	1.05	13.08	1.72	31.30	2.64
3- 2	0.77	4.80	1.10	25.68	2.42	0.28	0.06	9.79	1.54	12.40	2.11	22.12	2.22
3- 15	0.91	3.94	1.34	29.69	3.69	0.33	0.03	8.29	0.97	10.74	1.27	21.54	1.88
3- 17	0.65	4.19	0.95	28.47	2.62	0.27	0.03	8.98	0.86	11.55	0.99	20.33	1.61
3- 20	1.01	3.68	1.43	30.31	2.94	0.34	0.04	8.47	1.39	10.78	1.57	22.26	2.56
3- 22	0.76	3.64	0.87	32.80	1.76	0.43	0.04	8.90	0.86	10.54	0.98	27.24	3.14
5- 7	1.10	6.70	1.40	23.95	1.19	0.22	0.03	9.14	0.95	11.68	0.93	18.57	2.12
5- 8	1.15	5.58	1.52	23.98	1.45	0.22	0.04	9.38	0.71	11.95	1.05	18.94	1.84
6- 20	0.79	3.68	1.08	29.68	1.25	0.31	0.03	7.52	1.20	9.73	1.57	18.73	2.33
10- 2	0.45	3.49	0.73	38.57	3.45	0.55	0.04	7.23	0.48	8.24	0.74	28.73	1.72
10- 3	1.08	3.78	1.48	31.86	2.27	0.43	0.05	7.90	1.16	9.58	1.50	23.86	1.47
10- 7	2.75	5.37	3.65	36.25	2.34	0.35	0.03	8.14	1.38	10.73	1.55	22.53	2.30
10- 13	0.68	3.68	1.05	32.39	3.15	0.35	0.04	8.29	1.31	10.57	1.58	22.25	2.20
10- 17	1.09	4.17	1.51	28.37	2.36	0.35	0.04	8.13	0.94	10.72	1.17	22.45	1.21
10- 19	1.23	3.91	1.34	32.08	6.12	0.43	0.05	7.91	1.49	9.67	2.06	24.58	3.56
13- 2	1.47	4.50	1.83	28.71	2.54	0.35	0.04	9.08	1.55	11.41	1.71	23.55	2.19
13- 6	0.67	4.26	0.78	25.48	3.20	0.33	0.04	8.93	1.18	11.15	1.43	22.49	1.67
13- 15	1.17	4.38	1.48	28.24	2.53	0.34	0.05	8.71	1.42	10.75	1.92	22.13	2.73
13- 16	1.56	5.64	2.07	28.34	4.70	0.30	0.04	10.08	1.53	12.77	2.05	24.05	2.63
14- 2	0.82	4.15	1.23	29.02	2.68	0.34	0.04	8.44	0.93	10.69	0.94	22.05	2.35
14- 5	0.93	3.65	1.14	30.98	3.31	0.39	0.03	7.89	0.88	9.71	1.00	22.23	2.23
14- 14	0.68	4.01	0.94	25.74	2.21	0.30	0.03	8.16	0.77	10.01	1.08	18.67	1.55
14- 17	0.79	5.47	1.25	24.85	2.58	0.28	0.04	9.23	0.83	11.24	1.19	20.33	1.78
14- 18	0.59	4.77	0.82	26.61	1.17	0.29	0.07	9.42	0.62	11.30	1.04	21.02	3.59
14- 19	1.10	5.91	1.88	24.65	2.72	0.26	0.04	9.63	0.72	11.88	1.10	20.59	1.99
14- 20	1.37	5.00	2.15	26.14	2.18	0.27	0.03	9.25	0.44	11.36	0.60	19.93	1.19
16- 6	0.79	7.25	0.89	24.52	1.83	0.23	0.02	10.85	0.89	12.91	0.95	20.83	1.83
16- 7	0.76	7.25	0.87	23.85	1.06	0.21	0.02	10.86	0.94	13.05	1.00	20.30	1.38
16- 15	1.05	5.36	1.29	25.79	3.28	0.25	0.03	9.20	2.17	11.90	2.59	20.06	3.44

Appendix C: Dataset of "typical" crop signatures 1998

FULL_ID	287-1STD_DEV	287-2MEAN	287-2STD_DEV	287-3MEAN	287-3STD_DEV	320NDVI	320NDVI STD_DEV	320-1MEAN	320-1STD_DEV	320-2MEAN	320-2STD_DEV	320-3MEAN	320-3STD_DEV
16- 20	0.41	5.44	0.46	24.06	2.03	0.23	0.03	8.94	0.48	12.10	0.75	19.41	0.89
20- 2	0.76	5.17	1.16	26.31	2.52	0.27	0.03	10.21	0.76	13.09	1.06	22.79	1.31
20- 3	0.57	5.00	0.67	25.51	2.00	0.23	0.02	9.84	1.05	13.11	1.26	20.94	1.75
20- 10	0.76	4.69	1.00	26.51	1.51	0.25	0.03	8.95	0.57	12.02	0.61	20.33	1.44
20- 34	0.74	7.24	1.23	29.21	1.91	0.25	0.02	8.98	1.25	12.93	1.78	21.51	2.79
22- 14	0.75	5.46	1.28	25.27	1.54	0.25	0.02	10.72	1.12	13.63	1.46	23.07	2.71
27- 6	0.71	6.39	1.34	32.71	3.93	0.28	0.05	9.27	0.90	11.56	1.31	21.02	2.09
27- 17	1.15	6.77	2.05	25.84	3.50	0.24	0.05	11.59	1.35	14.50	1.94	23.70	1.68

Appendix C: Dataset of "typical" crop signatures 2001

FULL_ID	CROP98	SOW_D98	210NDVI	210NDVI SD	210-1MEAN	210-1STD_DEV	210-2MEAN	210-2STD_DEV	210-3MEAN	210-3STD_DEV	225NDVI	225NDVI SD	225-1MEAN	225-1STD_DEV
15- 52	Barley	20010618	0.32	0.04	9.29	1.11	9.49	1.17	18.57	2.07	0.45	0.06	8.52	0.71
3- 1	Barley		0.33	0.04	8.58	0.60	8.30	0.58	16.81	0.96	0.48	0.04	8.00	0.49
3- 5	Barley		0.37	0.05	6.97	0.88	7.16	1.16	15.93	2.47	0.55	0.06	6.88	0.66
3- 7	Barley		0.37	0.05	6.57	0.67	6.84	0.53	15.19	1.88	0.54	0.04	6.75	0.54
3- 23	Barley		0.39	0.09	6.76	0.96	7.39	1.19	17.13	3.37	0.54	0.06	6.76	0.72
10- 2	Barley	20010625	0.32	0.07	8.96	1.28	10.35	2.16	20.25	4.45	0.41	0.07	9.26	1.11
10-7	Barley	20010207	0.29	0.03	9.94	0.94	11.55	0.76	21.18	1.26	0.42	0.04	9.95	0.53
10- 12	Barley	20010706	0.28	0.06	10.86	1.42	11.91	1.54	21.44	1.86	0.36	0.06	10.14	1.00
10- 14	Barley	20010625	0.31	0.04	9.18	0.65	9.24	0.72	17.56	0.86	0.42	0.04	9.22	0.61
14- 8	Barley	20010619	0.29	0.06	11.85	1.15	12.59	1.55	23.07	1.18	0.38	0.05	10.38	0.80
14- 14	Barley	20010626	0.31	0.05	9.35	0.78	8.71	1.00	16.79	1.79	0.37	0.05	8.61	0.57
14- 17	Barley	20010625	0.35	0.09	8.09	0.98	7.65	1.27	16.36	2.53	0.40	0.06	8.04	0.82
14- 24	Barley	20010619	0.42	0.09	8.76	1.03	8.39	1.37	21.05	2.79	0.51	0.05	8.11	0.68
15- 30	Barley	20010618	0.32	0.07	8.91	0.74	8.77	0.89	17.25	1.69	0.41	0.06	8.99	0.67
16_4	Barley		0.31	0.03	10.97	0.72	9.88	0.69	18.84	0.99	0.43	0.05	10.39	0.71
16_17	Barley		0.54	0.06	8.43	0.75	7.73	1.04	26.56	2.09	0.60	0.08	8.24	0.56
16_19	Barley		0.61	0.07	7.32	0.66	6.20	0.92	26.40	4.64	0.65	0.08	7.18	0.85
16_21	Barley		0.52	0.08	7.54	0.89	7.00	1.36	22.89	4.77	0.61	0.07	7.16	0.75
16_25	Barley		0.54	0.07	8.05	1.27	7.60	1.82	24.57	2.54	0.56	0.06	8.28	1.22
3- 10	Canola		0.49	0.05	7.40	0.85	6.65	1.06	22.99	2.92	0.65	0.04	8.29	1.10
3- 19	Canola		0.34	0.05	7.40	0.55	7.18	0.64	21.38	2.20	0.42	0.08	6.75	0.46
10- 10	Canola	20010604	0.44	0.08	9.27	0.95	9.49	1.10	19.71	3.54	0.57	0.11	9.23	0.59
10- 11	Canola	20010517	0.48	0.06	9.16	0.78	9.54	1.00	25.42	4.46	0.60	0.07	8.75	0.55
10- 16	Canola	20010510	0.35	0.07	9.12	0.74	9.37	0.96	27.07	2.84	0.48	0.08	8.48	0.46
13- 5	Canola	20010610	0.29	0.04	9.56	0.82	9.20	0.93	19.58	2.45	0.39	0.05	9.08	0.64
13- 14	Canola	20010613	0.31	0.07	10.21	0.67	11.02	0.63	20.25	1.25	0.34	0.07	9.70	0.46
14- 5	Canola	20010629	0.38	0.06	7.63	0.59	8.22	0.61	16.02	2.30	0.45	0.05	8.38	0.56
15- 26	Canola	20010604	0.38	0.07	8.68	1.09	8.55	1.18	19.15	1.41	0.45	0.06	8.85	0.92
15- 28	Canola	20010604	0.33	0.04	7.84	0.79	8.02	0.93	18.10	1.61	0.42	0.05	8.52	0.76
15- 34	Canola	20010616	0.42	0.05	8.45	0.63	8.94	0.53	18.07	1.40	0.51	0.05	8.51	0.45
16_15	Canola		0.46	0.05	9.42	1.11	10.10	1.39	24.92	2.49	0.57	0.05	9.02	0.79
16_20	Canola		371.01	371.01	8.95	0.91	9.51	1.12	26.08	3.03	371.16	371.16	8.16	0.58
14- 3	Chickpeas	20010717	0.24	0.05	8.19	0.93	8.46	0.93	14.01	1.95	0.19	0.05	8.69	0.80
14- 4	Chickpeas	20010717	0.23	0.05	8.87	1.24	9.20	1.32	15.07	2.52	0.18	0.05	9.38	1.07
14- 15	Chickpeas	20010719	0.27	0.10	8.69	0.91	8.10	0.76	14.83	4.14	0.21	0.11	9.14	0.59
14- 16	Chickpeas	20010719	0.24	0.03	9.22	0.47	8.61	0.47	14.32	1.33	0.17	0.02	9.73	0.29
14- 18	Chickpeas	20010719	0.25	0.04	9.48	0.46	9.08	0.53	15.19	1.30	0.18	0.03	10.10	0.39
3- 12	Lentils		0.28	0.06	7.63	0.74	8.75	0.70	15.67	2.10	0.23	0.06	8.42	0.60
3- 14	Lentils		0.23	0.06	10.99	0.96	11.60	1.16	18.57	1.32	0.20	0.04	11.24	0.88
3- 16	Lentils		0.23	0.07	11.36	1.46	12.02	1.57	19.41	1.49	0.21	0.06	10.76	0.97
3- 21	Lentils		0.27	0.04	7.66	0.78	9.01	0.82	15.89	1.58	0.24	0.04	8.40	0.71
3- 24	Lentils		0.27	0.05	7.52	0.82	8.84	0.90	15.65	1.71	0.24	0.05	8.31	0.78
13- 12	Lentils	20010620	0.23	0.03	12.34	1.09	13.07	1.37	20.85	1.37	0.22	0.03	11.60	0.76
13- 13	Lentils	20010620	0.23	0.04	11.29	0.98	12.23	1.09	19.55	1.16	0.21	0.05	11.26	0.88
14- 10	Lentils	20010703	0.23	0.04	8.98	0.47	9.36	0.63	15.27	1.46	0.20	0.03	9.85	0.39
14- 12	Lentils	20010702	0.23	0.04	8.85	0.46	9.10	0.52	14.87	1.10	0.21	0.04	9.72	0.50

15- 14	Lentils	20010629	0.25	0.09	9.35	1.26	9.88	1.58	16.67	1.59	0.24	0.08	9.72	1.12
15- 15	Lentils	20010628	0.23	0.04	9.02	1.33	9.99	1.18	16.08	1.62	0.22	0.05	9.36	0.88
15- 44	Lentils	20010627	0.21	0.03	10.63	0.69	11.81	0.67	18.47	0.76	0.19	0.04	10.64	0.67
15- 49	Wheat	20010623	0.35	0.06	7.83	1.04	7.28	0.89	15.14	1.65	0.43	0.04	8.39	0.88
15- 50	Wheat	20010623	0.34	0.04	7.37	0.80	7.75	0.79	16.13	1.97	0.44	0.04	7.68	0.74
15- 51	Wheat	20010622	0.32	0.04	8.00	0.94	8.11	0.76	15.76	1.39	0.38	0.04	8.75	0.86
3- 2	Wheat		0.34	0.04	8.76	0.63	8.68	0.67	17.91	0.89	0.45	0.04	7.93	0.53
3- 3	Wheat		0.43	0.05	7.26	0.69	7.12	0.87	18.03	2.28	0.57	0.06	6.78	0.69
3- 4	Wheat		0.53	0.08	6.90	0.71	6.19	1.02	20.55	2.61	0.63	0.07	6.52	0.75
3- 9	Wheat		0.44	0.12	7.20	1.02	7.86	1.90	20.93	4.77	0.53	0.08	7.20	1.06
3- 13	Wheat		0.53	0.08	6.98	0.60	6.38	0.95	21.01	2.08	0.59	0.08	6.68	0.68
3- 20	Wheat		0.38	0.09	7.43	0.84	7.88	1.18	18.03	2.57	0.52	0.06	6.87	0.72
10- 1	Wheat	20010523	0.39	0.06	8.17	0.88	7.98	0.92	18.68	2.73	0.47	0.07	7.67	0.76
10- 3	Wheat	20010620	0.32	0.07	9.48	0.93	10.78	1.14	21.31	2.94	0.34	0.06	9.77	0.85
10- 4	Wheat	20010617	0.28	0.08	11.30	0.87	12.97	1.59	23.56	3.14	0.29	0.06	11.69	1.01
10- 6	Wheat	20010619	0.29	0.03	10.66	0.92	12.36	1.17	22.75	1.49	0.32	0.06	10.56	1.14
10- 17	Wheat	20010622	0.30	0.05	9.03	0.57	10.06	0.86	18.99	1.72	0.36	0.05	9.27	0.57
10- 18	Wheat	20010623	0.29	0.05	10.23	0.76	11.51	0.87	21.35	2.12	0.36	0.07	9.60	0.41
13- 1	Wheat	20010610	0.33	0.08	9.37	1.09	8.86	1.06	18.11	3.15	0.39	0.06	9.00	0.76
13-7	Wheat	20010615	0.33	0.07	8.96	0.91	8.56	0.80	17.30	2.59	0.39	0.06	9.01	0.64
13- 8	Wheat	20010620	0.44	0.04	8.00	0.56	7.85	0.57	20.45	1.51	0.55	0.04	7.65	0.49
13- 9	Wheat	20010610	0.44	0.04	7.48	0.63	7.37	0.79	18.96	1.63	0.56	0.05	7.16	0.56
13- 10	Wheat	20010610	0.47	0.05	7.65	0.49	7.25	0.68	20.45	1.88	0.59	0.05	7.06	0.41
13- 11	Wheat	20010615	0.33	0.05	9.18	0.77	9.06	0.94	18.12	0.98	0.40	0.05	8.84	0.56
14- 6	Wheat	20010602	0.38	0.05	8.43	0.67	8.34	0.60	18.94	1.21	0.45	0.06	8.12	0.48
14- 11	Wheat	20010530	0.40	0.06	7.66	0.63	7.64	0.73	18.06	2.05	0.43	0.07	7.84	0.58
14- 19	Wheat	20010615	0.43	0.08	8.47	0.96	7.73	1.21	19.61	2.57	0.48	0.07	8.05	1.00
14- 20	Wheat	20010615	0.42	0.04	8.60	0.92	7.61	1.20	19.03	2.67	0.54	0.08	7.70	0.78
14- 21	Wheat	20010612	0.47	0.07	8.24	0.90	7.31	1.18	20.56	3.49	0.53	0.08	7.83	0.91
14- 23	Wheat	20010612	0.48	0.10	8.49	0.72	7.46	1.03	22.73	6.66	0.56	0.08	7.84	0.78
15- 2	Wheat	20010621	0.35	0.04	6.91	0.59	7.22	0.73	15.14	1.67	0.47	0.03	7.04	0.41
15- 25	Wheat	20010602	0.49	0.09	7.58	1.40	6.91	1.98	20.10	2.68	0.53	0.10	7.61	1.42
15- 39	Wheat	20010529	0.46	0.04	7.44	0.65	7.18	0.68	19.51	1.81	0.53	0.04	7.57	0.57
16_2	Wheat		0.31	0.03	10.11	1.06	9.06	1.02	17.46	1.44	0.44	0.06	9.77	0.75
16_3	Wheat		0.28	0.03	10.90	0.79	9.86	0.86	17.81	1.14	0.39	0.03	10.70	0.72
16_7	Wheat		0.52	0.07	8.59	0.86	6.72	0.87	21.62	2.40	0.56	0.08	7.98	0.83

Appendix C: Dataset of "typical" crop signatures 2001

225-2MEAN	225-2STD_DEV	225-3MEAN	225-3STD_DEV	242 NDVI	242 NDVI SD	242-1MEAN	242-1STD_DEV	242-2MEAN	242-2STD_DEV	242-3MEAN	242-3STD_DEV	255NDVI	255NDVI SD
9.19	1.13	24.71	1.75	0.61	0.04	9.29	1.11	6.76	0.80	28.75	1.91	0.74	0.04
8.44	0.60	24.43	1.43	0.68	0.06	8.58	0.60	5.51	0.79	29.57	2.56	0.81	0.08
7.08	0.91	24.83	1.84	0.73	0.05	6.97	0.88	4.70	0.90	31.25	1.70	0.88	0.06
7.09	0.65	24.34	1.43	0.73	0.05	6.57	0.67	4.69	0.62	31.04	1.43	0.87	0.06
7.31	1.10	25.31	3.02	0.71	0.05	6.76	0.96	5.05	0.77	30.98	3.37	0.86	0.06
11.42	2.16	27.41	3.80	0.71	0.07	8.96	1.28	5.61	1.36	33.90	3.24	0.85	0.07
12.01	0.92	29.47	1.62	0.74	0.04	9.94	0.94	5.36	0.67	37.32	3.15	0.87	0.03
12.23	1.49	26.17	2.27	0.61	0.05	10.86	1.42	7.66	0.96	32.12	2.84	0.73	0.07
10.04	0.71	24.59	1.07	0.70	0.03	9.18	0.65	5.84	0.47	33.42	1.79	0.86	0.04
12.34	1.23	27.39	1.23	0.60	0.06	11.85	1.15	7.64	1.06	31.52	2.37	0.71	0.07
9.86	0.89	21.98	1.80	0.63	0.06	9.35	0.78	6.35	0.79	28.47	2.52	0.79	0.06
9.28	1.21	21.80	2.35	0.61	0.07	8.09	0.98	6.59	1.04	28.10	3.65	0.78	0.07
8.48	0.83	26.48	2.73	0.68	0.05	8.76	1.03	5.71	0.58	31.24	3.68	0.78	0.06
9.84	0.97	23.45	1.78	0.58	0.04	8.91	0.74	7.35	0.66	28.12	2.03	0.71	0.05
10.58	0.89	27.19	1.36	0.57	0.05	10.97	0.72	8.04	0.98	29.39	1.46	0.63	0.07
8.38	1.05	35.63	3.51	0.72	0.06	8.43	0.75	5.52	0.70	35.61	3.61	0.83	0.05
7.04	1.11	33.54	6.04	0.71	0.08	7.32	0.66	5.12	0.97	31.77	4.30	0.79	0.09
7.51	1.39	31.46	3.80	0.71	0.06	7.54	0.89	5.22	0.86	31.81	3.80	0.81	0.07
8.77	1.99	31.19	3.06	0.74	0.06	8.05	1.27	6.53	1.50	29.65	2.45	0.84	0.05
8.20	1.08	30.01	3.71	0.81	0.05	7.40	0.85	6.38	0.71	44.90	6.65	0.85	0.05
6.71	0.63	32.26	2.89	0.71	0.07	7.40	0.55	5.18	0.63	51.96	5.73	0.83	0.04
10.43	0.83	26.56	4.94	0.79	0.07	9.27	0.95	6.53	0.87	40.75	6.97	0.85	0.05
9.14	1.31	35.27	7.09	0.79	0.05	9.16	0.78	5.57	0.77	50.45	9.18	0.84	0.04
8.96	1.04	35.95	3.06	0.73	0.06	9.12	0.74	5.35	0.76	48.48	4.58	0.82	0.08
9.40	1.02	27.92	4.07	0.67	0.08	9.56	0.82	6.25	0.69	42.61	6.36	0.83	0.07
11.30	0.76	26.32	2.08	0.52	0.07	10.21	0.67	7.57	1.04	39.73	5.12	0.71	0.06
9.99	0.80	20.60	2.73	0.73	0.08	7.63	0.59	8.70	0.87	28.09	3.35	0.82	0.08
9.64	0.99	26.02	2.61	0.71	0.04	8.68	1.09	6.25	0.63	43.58	8.91	0.82	0.04
9.57	1.00	25.27	1.79	0.72	0.05	7.84	0.79	6.72	0.55	41.46	4.52	0.83	0.04
9.88	0.56	24.46	1.99	0.73	0.07	8.45	0.63	6.51	0.76	41.08	3.97	0.81	0.07
10.64	1.11	33.00	3.58	0.78	0.04	9.42	1.11	6.03	0.69	41.55	5.56	0.82	0.04
9.18	0.95	34.43	3.51	371.33	371.33	8.95	0.91	5.08	0.47	43.69	4.82	371.46	371.46
11.03	1.09	16.21	2.02	0.27	0.07	8.19	0.93	9.55	0.85	17.14	2.55	0.32	0.08
11.78	1.49	17.27	2.59	0.26	0.07	8.87	1.24	10.24	1.20	17.81	2.86	0.30	0.06
11.40	0.87	17.64	4.09	0.29	0.09	8.69	0.91	10.22	0.84	19.21	4.56	0.40	0.10
12.20	0.43	17.44	0.92	0.26	0.04	9.22	0.47	10.76	0.53	18.70	1.28	0.36	0.03
12.74	0.60	18.47	0.95	0.29	0.05	9.48	0.46	10.91	0.74	19.93	1.50	0.39	0.08
11.35	0.82	18.41	2.47	0.33	0.06	7.63	0.74	9.79	0.80	19.80	2.26	0.43	0.09
14.06	1.21	21.01	0.98	0.30	0.05	10.99	0.96	11.54	1.13	21.82	1.17	0.40	0.07
13.46	1.23	20.85	1.88	0.32	0.07	11.36	1.46	10.80	1.11	21.42	2.01	0.40	0.09
11.50	0.94	18.91	1.36	0.37	0.05	7.66	0.78	9.79	1.02	21.56	1.34	0.52	0.06
11.29	1.08	18.77	1.82	0.36	0.06	7.52	0.82	9.70	1.05	20.98	1.50	0.47	0.07
14.38	1.09	22.79	0.96	0.36	0.04	12.34	1.09	11.31	0.92	24.29	1.03	0.48	0.06
14.36	1.07	21.97	1.20	0.32	0.04	11.29	0.98	11.63	0.92	22.93	1.20	0.39	0.05
12.21	0.68	18.51	1.10	0.29	0.05	8.98	0.47	10.82	0.83	20.10	1.69	0.39	0.04
11.94	0.69	18.22	1.19	0.31	0.03	8.85	0.46	10.35	0.68	19.81	1.32	0.44	0.05

Appendix C: Dataset of "typical" crop signatures 2001

12.04	1.71	19.55	1.43	0.39	0.07	9.35	1.26	9.58	1.26	22.27	1.84	0.55	0.08
12.01	1.09	19.10	1.53	0.36	0.05	9.02	1.33	10.39	0.96	22.45	2.31	0.49	0.07
13.98	0.98	20.72	1.07	0.30	0.04	10.63	0.69	11.78	0.90	22.31	1.24	0.42	0.05
8.74	0.89	22.29	1.93	0.64	0.04	7.83	1.04	6.13	0.60	28.59	2.37	0.83	0.06
8.71	0.91	22.86	1.80	0.68	0.04	7.37	0.80	5.37	0.69	28.72	1.63	0.84	0.04
9.84	0.94	22.24	1.37	0.62	0.04	8.00	0.94	6.61	0.72	28.94	0.97	0.82	0.03
8.99	0.81	23.69	1.37	0.67	0.04	8.76	0.63	5.33	0.60	27.24	1.90	0.82	0.05
7.04	1.06	26.13	2.04	0.75	0.06	7.26	0.69	4.18	0.92	30.60	2.00	0.87	0.07
6.39	1.12	28.01	3.29	0.74	0.08	6.90	0.71	4.59	1.14	32.04	3.37	0.86	0.09
8.36	1.94	27.36	4.01	0.72	0.07	7.20	1.02	4.87	1.02	31.59	3.90	0.84	0.09
6.91	1.04	27.19	2.63	0.71	0.06	6.98	0.60	4.75	0.87	28.99	2.04	0.85	0.06
7.60	1.01	24.56	2.36	0.70	0.04	7.43	0.84	4.93	0.79	28.89	2.35	0.85	0.06
8.44	1.19	23.73	2.42	0.67	0.06	8.17	0.88	5.66	1.12	29.30	2.81	0.83	0.05
12.51	1.45	25.88	2.49	0.56	0.06	9.48	0.93	7.50	1.03	27.43	3.06	0.74	0.07
15.21	1.89	28.03	2.47	0.53	0.06	11.30	0.87	8.08	1.06	26.55	3.30	0.71	0.08
13.90	1.76	27.08	1.63	0.57	0.06	10.66	0.92	6.97	0.87	25.84	2.55	0.77	0.06
11.40	1.01	24.28	1.71	0.64	0.05	9.03	0.57	6.13	0.72	28.62	2.69	0.82	0.04
11.96	0.82	25.32	2.48	0.62	0.05	10.23	0.76	6.80	0.66	29.52	3.71	0.79	0.05
9.77	0.89	22.56	2.94	0.59	0.05	9.37	1.09	6.46	0.70	26.09	2.89	0.76	0.06
9.74	0.80	22.62	2.52	0.61	0.04	8.96	0.91	6.35	0.70	26.80	2.72	0.78	0.04
8.17	0.80	28.02	1.71	0.73	0.03	8.00	0.56	5.08	0.63	33.55	2.46	0.87	0.05
7.47	0.80	26.71	2.18	0.72	0.05	7.48	0.63	4.93	0.83	31.30	2.51	0.85	0.06
7.18	0.75	28.01	2.07	0.73	0.05	7.65	0.49	4.82	0.77	31.66	2.39	0.84	0.04
9.65	0.75	22.80	1.25	0.60	0.05	9.18	0.77	6.42	0.73	26.53	1.93	0.77	0.06
8.94	0.62	23.83	2.10	0.54	0.06	8.43	0.67	7.30	0.82	25.00	2.49	0.64	0.07
9.02	0.85	23.04	2.43	0.52	0.06	7.66	0.63	7.59	0.73	24.64	2.60	0.62	0.07
9.13	1.57	25.61	2.88	0.64	0.11	8.47	0.96	6.40	1.62	30.96	4.80	0.77	0.11
7.92	1.25	27.21	2.79	0.73	0.08	8.60	0.92	5.27	1.36	34.58	4.29	0.82	0.08
8.42	1.55	27.92	4.86	0.66	0.08	8.24	0.90	6.22	1.18	31.14	5.02	0.78	0.09
8.25	1.31	30.63	6.20	0.69	0.07	8.49	0.72	6.09	1.19	34.13	4.95	0.80	0.07
7.80	0.59	21.86	1.87	0.67	0.05	6.91	0.59	5.17	0.74	26.95	2.10	0.82	0.03
7.91	2.47	25.73	2.95	0.62	0.10	7.58	1.40	6.43	2.45	27.65	2.54	0.72	0.11
7.95	0.75	26.58	1.82	0.68	0.03	7.44	0.65	5.74	0.63	30.85	1.93	0.81	0.03
9.90	1.06	25.89	1.56	0.67	0.07	10.11	1.06	5.91	1.13	30.34	2.32	0.85	0.06
11.05	0.77	25.35	1.29	0.59	0.03	10.90	0.79	7.20	0.71	28.36	1.26	0.80	0.03
7.77	1.13	28.47	2.96	0.66	0.07	8.59	0.86	5.60	0.99	27.87	2.47	0.78	0.06

Appendix C: Dataset of "typical" crop signatures 2001

255-1MEAN	255-1STD_DEV	255-2MEAN	255-2STD_DEV	255-3MEAN	255-3STD_DEV	282NDVI	282NDVI SD	282-1MEAN	282-1STD_DEV	282-2MEAN	282-2STD_DEV	282-3MEAN	282-3STD_DEV
3.86	0.45	4.44	0.70	30.08	2.05	0.57	0.04	6.99	0.53	7.96	0.80	29.42	2.11
3.09	0.64	3.08	1.02	31.88	3.50	0.76	0.07	4.92	0.75	4.59	1.10	34.44	3.15
2.38	0.83	2.25	1.20	35.11	2.80	0.73	0.07	5.79	1.02	5.40	1.69	35.99	3.30
2.24	0.57	2.14	0.70	34.17	2.11	0.72	0.04	6.05	0.41	5.84	0.59	36.48	2.53
2.14	0.43	2.27	0.70	33.28	4.28	0.70	0.05	6.07	0.75	6.05	0.97	35.41	3.71
3.47	0.71	3.25	1.34	42.52	6.08	0.79	0.09	5.78	0.82	4.88	1.68	45.76	6.76
3.58	0.26	3.08	0.63	46.18	3.47	0.85	0.03	5.40	0.37	3.99	0.49	51.97	3.26
4.84	0.75	5.21	1.16	35.07	4.66	0.73	0.13	6.37	1.98	6.09	3.03	40.54	5.99
3.30	0.32	2.84	0.33	41.18	3.43	0.80	0.04	5.72	0.29	4.69	0.42	43.50	3.59
4.86	0.70	5.71	1.15	34.81	3.26	0.73	0.05	5.57	0.62	5.40	0.97	35.63	2.74
3.63	0.41	3.85	0.62	34.28	3.91	0.77	0.05	5.09	0.60	4.59	0.79	36.88	3.18
3.37	0.53	3.67	1.01	31.53	5.27	0.69	0.09	6.05	0.76	6.10	1.32	35.01	5.34
3.81	0.40	4.05	0.51	34.10	5.40	0.69	0.06	5.71	0.58	5.91	0.68	32.77	4.59
4.20	0.43	4.58	0.63	28.43	2.64	0.60	0.05	6.59	0.34	7.03	0.60	29.01	2.56
5.19	0.68	5.84	0.96	26.82	2.53	0.47	0.05	8.85	0.73	9.87	0.92	28.03	1.57
3.04	0.55	3.32	0.89	37.23	3.99	0.69	0.06	6.24	0.48	6.65	0.98	37.52	3.33
3.02	0.80	3.45	1.08	31.60	4.86	0.62	0.07	6.11	1.05	7.13	1.51	30.62	3.50
2.96	1.03	3.38	1.27	32.34	4.09	0.65	0.08	5.96	0.87	6.88	1.60	32.28	2.50
3.52	0.64	4.25	1.23	27.51	3.21	0.62	0.04	7.33	0.98	9.11	1.59	30.28	2.42
4.33	0.54	3.82	0.58	48.71	7.99	0.63	0.03	7.51	0.80	7.96	0.83	34.45	3.35
3.85	0.37	3.77	0.69	50.58	6.00	0.67	0.03	7.46	0.46	7.95	0.42	35.94	2.75
4.76	0.28	4.27	0.50	47.14	6.36	0.68	0.04	10.38	0.94	10.22	0.96	53.01	3.73
4.47	0.26	4.00	0.41	53.07	7.90	0.69	0.04	9.16	1.12	9.15	1.13	48.74	5.16
4.48	0.29	4.03	0.56	48.85	4.19	0.68	0.05	8.63	0.76	8.40	0.84	46.43	3.52
4.72	0.38	4.19	0.73	49.41	7.45	0.64	0.04	10.24	1.33	10.01	1.20	53.99	8.21
4.79	0.49	4.42	1.28	48.48	6.62	0.72	0.06	9.92	0.76	10.06	0.74	46.75	5.30
5.20	0.51	5.70	0.69	34.65	4.35	0.59	0.05	7.51	0.82	7.14	0.94	45.42	5.26
4.51	0.45	4.11	0.51	48.95	10.62	0.57	0.03	8.47	0.94	9.20	0.90	36.84	5.82
4.90	0.58	4.42	0.47	45.67	6.01	0.60	0.03	8.62	0.99	9.52	1.12	35.52	2.84
4.53	0.24	4.01	0.45	46.87	3.92	0.61	0.06	8.60	0.67	9.31	0.70	37.88	3.05
4.29	0.35	4.24	0.75	42.57	6.11	0.71	0.06	8.61	0.86	9.54	0.98	40.97	5.60
4.12	0.47	4.10	0.45	43.81	4.77	371.73	371.73	6.82	0.39	6.89	0.83	42.79	4.50
6.19	0.82	9.03	1.16	18.17	2.96	0.43	0.07	8.04	0.80	9.61	1.12	24.85	2.76
6.81	1.01	9.81	1.37	18.65	2.63	0.41	0.06	8.53	0.92	10.27	1.23	25.23	2.77
5.40	0.59	7.66	0.94	18.47	5.05	0.48	0.05	8.25	0.86	9.65	1.10	28.07	2.27
5.64	0.32	8.04	0.48	17.26	1.52	0.47	0.04	8.38	0.41	9.69	0.54	27.63	2.23
5.90	0.51	8.17	0.91	19.25	2.26	0.54	0.06	8.05	0.64	9.07	0.96	31.01	2.40
5.46	0.58	8.28	0.88	20.70	2.49	0.66	0.05	6.35	0.48	6.66	0.79	32.87	2.63
6.65	0.61	9.08	0.95	21.10	1.45	0.66	0.06	6.90	0.68	6.92	1.17	35.02	3.24
7.00	1.03	9.43	1.42	22.55	2.12	0.66	0.06	6.74	0.63	6.64	1.12	33.69	3.02
5.00	0.54	7.32	0.83	23.28	1.44	0.76	0.05	5.93	0.68	5.38	1.18	39.63	2.60
5.05	0.55	7.68	0.98	21.58	1.59	0.70	0.05	5.94	0.61	5.91	1.00	34.95	2.25
7.20	0.64	9.01	0.98	25.73	1.37	0.75	0.05	6.69	0.41	6.02	0.76	42.74	4.67
7.34	0.67	9.89	0.86	22.89	1.32	0.67	0.05	7.02	0.43	7.09	0.88	36.15	2.75
6.22	0.48	8.63	0.74	20.06	1.57	0.62	0.04	7.72	0.53	8.21	0.85	35.16	2.12
5.86	0.38	7.91	0.54	20.46	1.44	0.65	0.05	7.31	0.46	7.43	0.79	36.53	2.93

5.55	0.76	6.88	1.11	24.47	3.23	0.64	0.08	6.45	0.39	6.90	0.97	32.63	4.23
6.24	0.56	8.18	0.92	24.46	2.72	0.66	0.04	6.48	0.32	6.88	0.66	34.06	2.19
6.54	0.44	9.12	0.82	22.77	1.59	0.69	0.05	6.62	0.38	6.73	0.77	37.05	2.59
2.72	0.38	2.95	0.57	33.55	3.44	0.62	0.04	6.79	0.40	7.51	0.62	32.63	2.29
2.58	0.43	2.77	0.52	35.34	2.55	0.67	0.04	5.77	0.58	6.29	0.77	32.43	2.11
3.11	0.34	3.20	0.50	33.65	1.66	0.64	0.04	6.53	0.39	7.00	0.69	32.52	1.43
2.39	0.51	2.89	0.71	32.10	2.26	0.78	0.04	4.41	0.58	4.22	0.68	34.37	1.77
1.99	0.85	2.28	1.18	34.41	2.58	0.73	0.05	4.86	0.82	4.88	1.18	32.51	2.45
2.14	0.78	2.43	1.18	34.58	4.83	0.73	0.06	4.70	0.69	4.86	0.89	32.32	3.50
2.47	0.82	2.73	1.23	36.78	6.01	0.77	0.12	4.73	1.03	4.64	1.74	38.69	7.16
1.83	0.56	2.28	0.74	30.91	1.85	0.71	0.03	5.19	0.52	5.16	0.61	31.10	1.53
2.05	0.52	2.42	0.74	31.67	3.10	0.72	0.05	5.15	0.76	5.17	1.12	32.67	3.16
2.84	0.80	3.16	1.16	34.73	3.48	0.74	0.05	5.48	0.60	5.12	1.06	35.48	2.73
3.50	0.98	4.38	1.63	29.20	3.55	0.71	0.08	5.45	1.02	5.84	1.85	34.93	2.95
3.80	1.09	4.89	1.63	29.21	2.88	0.69	0.07	5.99	1.36	6.58	2.09	37.05	2.56
3.11	0.40	3.81	0.72	30.53	3.67	0.77	0.04	4.67	0.62	4.83	0.83	37.59	1.99
2.61	0.51	2.93	0.60	31.65	3.71	0.83	0.05	3.95	0.69	3.53	0.97	39.92	3.33
3.35	0.46	3.64	0.67	33.73	3.69	0.81	0.08	4.30	1.63	3.97	2.04	39.13	3.25
3.42	0.62	3.99	0.91	29.79	3.53	0.74	0.07	4.81	0.96	4.70	1.34	31.88	3.55
3.22	0.57	3.68	0.93	30.42	3.05	0.80	0.06	4.24	0.89	3.83	1.37	34.93	3.07
2.20	0.61	2.33	1.08	34.06	3.03	0.70	0.02	5.62	0.25	5.71	0.34	33.35	1.79
2.32	0.57	2.54	0.83	33.91	3.32	0.77	0.05	4.75	0.92	4.50	1.34	34.53	2.63
2.39	0.51	2.85	0.88	32.42	2.90	0.70	0.05	5.05	0.56	5.20	0.94	30.71	2.95
3.09	0.55	3.58	0.79	29.63	3.07	0.77	0.05	4.47	0.67	4.15	0.89	33.38	2.31
4.31	0.56	5.54	0.91	25.72	2.89	0.60	0.06	6.22	0.39	6.89	0.76	28.50	3.00
3.73	0.55	5.26	0.83	23.45	2.87	0.55	0.05	6.58	0.50	7.74	0.88	27.87	2.65
3.56	0.83	4.07	1.58	32.33	6.03	0.59	0.07	6.64	0.96	7.82	1.60	30.68	4.32
3.54	1.04	3.58	1.86	37.54	4.86	0.60	0.07	7.11	1.38	8.30	2.22	32.81	2.13
3.06	0.68	3.61	1.19	31.90	6.42	0.64	0.07	6.22	0.78	7.07	1.33	33.51	4.70
3.08	0.74	3.58	1.12	35.09	5.54	0.64	0.08	6.25	0.90	7.21	1.51	33.62	3.70
2.47	0.36	2.92	0.58	29.83	3.18	0.61	0.04	6.38	0.28	7.05	0.47	29.83	2.40
3.54	1.70	4.47	2.55	27.14	2.59	0.64	0.10	5.80	1.47	6.30	2.33	28.90	3.12
2.62	0.54	3.19	0.57	30.45	2.19	0.59	0.03	6.61	0.32	7.64	0.51	30.18	1.95
2.62	0.80	2.68	0.99	34.10	2.85	0.66	0.10	6.41	1.51	6.65	1.97	32.75	2.37
3.36	0.39	3.40	0.56	32.04	2.17	0.55	0.03	7.76	0.65	8.52	0.66	30.03	1.03
2.96	0.74	3.39	0.95	28.97	2.83	0.52	0.04	7.22	0.66	8.39	0.77	26.92	1.48

319NDVI	319NDVI SD	319-1MEAN	319-1STD_DEV	319-2MEAN	319-2STD_DEV	319-3MEAN	319-3STD_DEV
0.18	0.03	13.34	0.81	17.70	1.14	27.64	1.55
0.28	0.04	12.91	0.93	17.48	1.74	33.48	1.93
0.27	0.06	12.18	0.93	16.41	1.45	31.02	2.00
0.25	0.06	11.69	0.89	15.84	1.47	28.08	1.32
0.24	0.06	11.95	1.18	16.50	2.08	28.79	2.00
0.29	0.06	12.55	1.35	17.79	2.37	34.96	3.45
0.29	0.04	13.68	1.07	19.89	1.89	38.37	2.44
0.36	0.06	11.63	1.28	15.61	2.02	34.97	2.23
0.29	0.03	12.82	0.97	17.77	1.60	34.36	2.31
0.37	0.04	9.65	0.89	12.97	1.16	29.79	1.34
0.30	0.04	10.87	0.76	14.74	1.10	29.07	2.08
0.26	0.06	12.22	1.41	16.46	2.47	29.82	2.81
0.32	0.03	9.35	0.67	12.95	1.11	27.13	1.66
0.23	0.03	12.89	0.88	16.99	1.14	29.24	1.35
0.17	0.02	15.40	0.80	19.58	1.07	29.81	0.84
0.23	0.05	13.23	1.27	18.25	2.11	30.86	2.51
0.22	0.05	12.64	1.25	17.14	2.20	28.76	2.10
0.21	0.04	12.50	1.11	17.40	1.97	28.62	2.43
0.41	0.04	14.61	1.75	20.22	2.67	32.81	1.98
0.48	0.07	10.34	0.56	11.58	0.92	29.82	1.78
0.60	0.08	9.44	0.44	10.53	0.99	32.06	1.93
0.50	0.06	10.58	0.43	10.46	1.41	43.74	3.94
0.44	0.05	10.82	0.48	12.04	1.11	39.12	2.94
0.67	0.09	11.25	0.39	12.93	0.74	36.61	2.04
0.55	0.07	9.58	0.52	8.52	1.49	46.75	5.49
0.49	0.08	10.35	0.56	10.55	1.33	38.29	2.58
0.44	0.08	9.59	0.68	10.63	1.34	33.38	2.94
0.37	0.05	11.04	0.66	12.27	0.78	33.73	4.00
0.41	0.04	11.29	0.60	13.49	0.89	30.99	1.82
0.29	0.03	9.95	0.49	12.60	0.69	32.03	1.62
0.27	0.03	12.83	1.19	17.49	1.65	34.08	2.77
372.10	372.10	12.76	0.88	17.37	1.25	33.07	1.34
0.55	0.07	8.97	0.47	9.48	1.17	34.21	3.47
0.56	0.08	9.13	0.57	9.52	1.28	36.25	3.48
0.46	0.09	9.97	0.98	11.30	1.66	33.14	2.15
0.52	0.05	9.64	0.62	10.41	1.26	34.54	1.04
0.51	0.07	9.74	0.74	10.68	1.61	33.92	2.47
0.59	0.05	9.05	0.62	9.30	1.15	37.03	2.20
0.59	0.08	9.52	0.81	9.42	1.41	38.69	2.84
0.60	0.10	9.00	0.81	8.82	1.85	36.88	3.16
0.52	0.07	10.35	0.78	11.14	1.46	37.99	1.91
0.50	0.07	10.01	0.72	11.09	1.34	35.60	2.53
0.58	0.04	10.81	0.75	10.43	0.87	42.12	3.45
0.57	0.08	10.22	0.53	10.12	1.10	39.89	3.49
0.52	0.07	10.29	0.66	11.13	1.49	37.04	1.75
0.53	0.06	10.15	0.45	10.55	0.84	37.05	2.24

0.39	0.06	10.95	0.84	13.27	1.22	32.12	3.79
0.36	0.06	11.05	0.60	14.29	1.29	32.23	2.36
0.41	0.05	11.72	0.54	14.18	0.91	36.21	1.86
0.23	0.03	12.80	1.11	16.25	1.54	28.02	1.99
0.25	0.03	10.92	0.84	14.26	1.26	25.37	2.17
0.22	0.02	11.88	0.53	15.67	0.61	26.43	1.29
0.42	0.05	8.97	0.54	10.76	1.27	27.72	1.31
0.37	0.04	9.24	0.79	11.25	1.36	26.22	2.58
0.35	0.04	9.57	1.05	12.35	1.69	27.02	2.41
0.44	0.07	9.34	0.56	11.75	0.93	31.80	3.86
0.35	0.03	9.40	0.41	11.67	0.63	25.79	1.53
0.32	0.04	9.43	0.77	12.13	1.28	25.43	1.92
0.29	0.02	9.89	0.95	12.89	1.36	25.30	1.87
0.33	0.04	10.80	1.01	14.44	1.55	30.29	2.22
0.37	0.04	11.31	0.97	14.67	1.63	33.28	1.90
0.37	0.05	9.68	0.81	12.85	1.36	29.30	1.53
0.49	0.05	9.11	0.48	11.25	0.94	34.75	2.17
0.48	0.07	8.59	1.16	10.33	1.78	30.60	2.66
0.35	0.04	9.18	1.03	11.26	1.63	25.11	2.70
0.45	0.06	7.91	1.17	9.21	1.81	25.32	3.09
0.28	0.02	10.67	0.31	14.02	0.56	26.92	0.94
0.34	0.04	9.07	0.98	11.35	1.68	24.62	2.70
0.31	0.05	9.17	0.83	11.57	1.48	23.60	2.45
0.37	0.04	8.56	0.91	10.48	1.44	24.20	2.82
0.26	0.03	10.22	0.47	13.30	0.71	24.73	1.31
0.26	0.05	11.56	1.00	15.01	1.39	27.91	2.20
0.29	0.05	10.63	0.97	13.67	1.74	27.08	2.85
0.26	0.03	10.78	0.94	13.95	1.34	25.37	2.29
0.30	0.04	10.50	1.11	13.65	1.81	27.12	3.34
0.29	0.04	10.76	0.98	14.10	1.55	27.21	2.66
0.24	0.02	10.79	0.41	14.22	0.76	24.57	1.53
0.31	0.05	10.13	1.33	13.06	2.18	26.29	2.11
0.26	0.03	11.33	0.58	14.98	0.85	27.31	0.78
0.22	0.03	13.44	0.79	17.51	1.07	29.27	1.67
0.19	0.01	13.72	0.45	17.15	0.75	27.01	1.16
0.19	0.02	12.78	0.64	16.12	0.88	25.67	1.40

Appendix D: Single Date Crop Discrimination Model Results

1998

DOY 181	Model I	Model II	Model III	Model IV
Barley	21.43	28.57	28.57	50.00
Canola	35.48	38.71	45.16	54.84
Chickpeas	40.00	60.00	40.00	70.00
Lentils	55.56	55.56	66.67	66.67
Wheat	66.67	63.89	61.11	66.67

DOY 221	Model I	Model II	Model III	Model IV
Barley	35.71	50.00	42.86	64.29
Canola	74.19	74.19	77.42	77.42
Chickpeas	50.00	50.00	70.00	70.00
Lentils	55.56	44.44	66.67	55.56
Wheat	83.33	83.33	83.33	83.33

DOY 240	Model I	Model II	Model III	Model IV
Barley	50.00	64.29	64.29	71.43
Canola	83.87	83.87	87.10	87.10
Chickpeas	50.00	60.00	70.00	70.00
Lentils	44.44	44.44	55.56	88.89
Wheat	80.56	80.56	83.33	83.33

DOY 251	Model I	Model II	Model III	Model IV
Barley	57.14	57.14	64.29	78.57
Canola	80.65	80.65	80.65	83.87
Chickpeas	50.00	50.00	60.00	60.00
Lentils	33.33	33.33	66.67	77.78
Wheat	72.22	77.14	86.11	88.57

DOY 287	Model I	Model II	Model III	Model IV
Barley	50.00	50.00	71.43	71.43
Canola	54.84	58.06	58.06	67.74
Chickpeas	50.00	50.00	50.00	70.00
Lentils	88.89	44.44	88.89	88.89
Wheat	80.56	77.78	83.33	86.11

DOY 320	Model I	Model II	Model III	Model IV
Barley	78.57	64.29	78.57	85.71
Canola	64.52	70.97	70.97	70.97
Chickpeas	80.00	80.00	90.00	90.00
Lentils	33.33	33.33	44.44	44.44
Wheat	86.11	83.33	86.11	91.67

2001

DOY 210	Model I	Model II	Model III	Model IV
Barley	10.53	10.53	26.32	31.58
Canola	46.15	46.15	61.54	53.85
Chickpeas	100.00	100.00	100.00	100.00
Lentils	83.33	83.33	83.33	83.33
Wheat	60.61	63.64	48.48	48.48

DOY 225	Model I	Model II	Model III	Model IV
Barley	21.05	31.58	31.58	47.37
Canola	46.15	46.15	84.62	76.92
Chickpeas	80.00	80.00	100.00	100.00
Lentils	75.00	83.33	75.00	75.00
Wheat	57.58	57.58	60.61	57.58

DOY 242	Model I	Model II	Model III	Model IV
Barley	68.42	68.42	78.95	78.95
Canola	92.31	92.31	92.31	100.00
Chickpeas	80.00	80.00	100.00	80.00
Lentils	66.67	66.67	83.33	91.67
Wheat	72.73	72.73	81.82	81.82

DOY 255	Model I	Model II	Model III	Model IV
Barley	57.89	63.16	63.16	63.16
Canola	92.31	92.31	92.31	92.31
Chickpeas	100.00	100.00	100.00	100.00
Lentils	66.67	75.00	83.33	91.67
Wheat	84.85	84.85	87.88	84.85

DOY 282	Model I	Model II	Model III	Model IV
Barley	42.11	42.11	47.37	47.37
Canola	76.92	84.62	84.62	92.31
Chickpeas	100.00	100.00	100.00	100.00
Lentils	58.33	66.67	83.33	83.30
Wheat	81.82	81.82	72.73	72.73

DOY 319	Model I	Model II	Model III	Model IV
Barley	89.47	89.47	84.21	84.21
Canola	23.08	23.08	38.46	46.15
Chickpeas	100.00	100.00	80.00	100.00
Lentils	58.33	58.33	58.33	58.33
Wheat	87.88	87.88	87.88	87.88

Appendix E: Progressive Date Crop Discrimination Model Results

1998

DOY 181	Model I	Model II	Model III	Model IV
Barley	21.43	28.57	28.57	50.00
Canola	35.48	38.71	45.16	54.84
Chickpeas	40.00	60.00	40.00	70.00
Lentils	55.56	55.56	66.67	66.67
Wheat	66.67	63.89	61.11	66.67

DOY 221	Model I	Model II	Model III	Model IV
Barley	50.00	71.43	71.43	71.43
Canola	83.87	83.87	90.32	87.10
Chickpeas	70.00	60.00	70.00	70.00
Lentils	77.78	55.56	77.78	88.89
Wheat	86.11	91.67	88.89	91.67

DOY 240	Model I	Model II	Model III	Model IV
Barley	64.29	71.43	78.57	92.86
Canola	80.65	80.65	83.87	83.87
Chickpeas	70.00	90.00	70.00	80.00
Lentils	77.78	88.89	88.89	100.00
Wheat	88.89	91.67	91.67	100.00

DOY 251	Model I	Model II	Model III	Model IV
Barley	71.43	78.57	100.00	100.00
Canola	90.32	93.55	93.55	93.55
Chickpeas	70.00	90.00	80.00	80.00
Lentils	88.89	88.89	77.78	100.00
Wheat	88.89	97.14	94.44	97.14

DOY 287	Model I	Model II	Model III	Model IV
Barley	85.71	92.86	100.00	100.00
Canola	90.32	90.32	93.55	100.00
Chickpeas	70.00	90.00	80.00	100.00
Lentils	66.67	88.89	77.78	100.00
Wheat	94.44	97.14	94.44	100.00

DOY 320	Model I	Model II	Model III	Model IV
Barley	92.86	100.00	100.00	100.00
Canola	90.32	93.55	100.00	100.00
Chickpeas	90.00	100.00	100.00	100.00
Lentils	66.67	100.00	100.00	100.00
Wheat	94.44	97.14	94.44	100.00

2001

DOY 210	Model I	Model II	Model III	Model IV
Barley	10.53	10.53	26.32	31.58
Canola	46.15	46.15	61.54	53.85
Chickpeas	100.00	100.00	100.00	100.00
Lentils	83.33	83.33	83.33	83.33
Wheat	60.61	63.64	48.48	48.48

DOY 225	Model I	Model II	Model III	Model IV
Barley	52.63	52.63	63.16	63.16
Canola	53.85	61.54	76.92	76.92
Chickpeas	80.00	80.00	80.00	80.00
Lentils	100.00	100.00	100.00	100.00
Wheat	72.73	72.73	75.76	78.79

DOY 242	Model I	Model II	Model III	Model IV
Barley	78.95	73.68	78.95	78.95
Canola	92.31	100.00	92.31	100.00
Chickpeas	100.00	100.00	100.00	100.00
Lentils	100.00	100.00	100.00	100.00
Wheat	75.76	81.82	78.79	90.91

DOY 255	Model I	Model II	Model III	Model IV
Barley	89.47	89.47	100.00	100.00
Canola	100.00	100.00	100.00	100.00
Chickpeas	100.00	100.00	100.00	100.00
Lentils	91.67	100.00	100.00	100.00
Wheat	93.94	93.94	90.91	90.91

DOY 282	Model I	Model II	Model III	Model IV
Barley	89.47	94.74	100.00	94.74
Canola	100.00	100.00	100.00	100.00
Chickpeas	100.00	100.00	100.00	100.00
Lentils	100.00	100.00	100.00	100.00
Wheat	93.94	93.94	96.97	100.00

DOY 319	Model I	Model II	Model III	Model IV
Barley	100.00	100.00	100.00	100.00
Canola	100.00	100.00	100.00	100.00
Chickpeas	100.00	100.00	100.00	100.00
Lentils	100.00	100.00	100.00	100.00
Wheat	100.00	100.00	100.00	100.00

Appendix F: Result Differences 1998-2001

Single Date Model Result Differences 1998- 2001

DOY	Mean B1-3	Mean B1-3, NDVI	Mean B1-3, Stdv B1-3	Mean B1-3, Stdv B1-3, NDVI, Stdv NDVI
Date 1	-0.0330	0.0166	-0.0833	0.0509
Date 2	0.1533	0.1445	0.0696	0.0888
Date 3	-0.1060	-0.0947	-0.1166	-0.0810
Date 4	-0.1280	-0.1879	-0.1167	-0.0734
Date 5	-0.0501	-0.1091	0.0229	0.0383
Date 6	0.0043	-0.0294	0.0641	0.1128

Progressive Dates Model Result Differences 1998- 2001

DOY	Mean B1-3	Mean B1-3, NDVI	Mean B1-3, Stdv B1-3	Mean B1-3, Stdv B1-3, NDVI, Stdv NDVI
Date 1	-0.0330	0.0166	-0.0833	0.0509
Date 2	0.0537	0.1121	0.0513	0.0477
Date 3	-0.1130	-0.0947	-0.0382	-0.0012
Date 4	-0.1666	-0.0845	-0.0946	-0.0336
Date 5	-0.1374	-0.0858	-0.1322	0.0331
Date 6	-0.2188	-0.0826	-0.0525	0.0000

DOY	Field Name	Farm_n	Field_no	Northing	Easting	Crop Type	Plant Height [cm]	Wet Plant Weight [g/m2]	Dry Plant Weight [g/m2]	Plant Water [g/m2]	Plant Water [%]
168	Crofts West	15	16	5981831	699236	barley					
203	Crofts West	15	16	5981831	699236	barley	10	34	7	27	0.79
238	Crofts West	15	16	5981831	699236	barley	25	403	62	341	0.85
273	Crofts West	15	16	5981831	699236	barley					
168	Lynas West House	15	41	5984295	701830	barley	3				
203	Lynas West House	15	41	5984295	701830	barley	25				
238	Lynas West House	15	41	5984295	701830	barley	35	1628	237	1391	0.85
273	Lynas West House	15	41	5984295	701830	barley	65	1182	443	738	0.62
308	Lynas West House	15	41	5984295	701830	barley	72	1454	550	903	0.62
343	Lynas West House	15	41	5984295	701830	barley					
168	Merrillees	14	8	5970671	703609	barley	8				
203	Merrillees	14	8	5970671	703609	barley	8	46	8	38	0.83
168	Adelines	14	23	5976169	688037	canola	6	24			
203	Adelines	14	23	5976169	688037	canola	15	356	41	315	0.88
238	Adelines	14	23	5976169	688037	canola	40	2101	201	1899	0.90
273	Adelines	14	23	5976169	688037	canola	115	1878	347	1530	0.82
308	Adelines	14	23	5976169	688037	canola	90	2307	628	1679	0.73
343	Adelines	14	23	5976169	688037	canola					
168	Bourkes South	15	32	5978027	697972	canola	7	215			
203	Bourkes South	15	32	5978027	697972	canola	10	214	21	193	0.90
238	Bourkes South	15	32	5978027	697972	canola	85	2257	288	1968	0.87
273	Bourkes South	15	32	5978027	697972	canola	105	1328	395	933	0.70
308	Bourkes South	15	32	5978027	697972	canola		854	324	529	0.62
343	Bourkes South	15	32	5978027	697972	canola					
168	Dews One	15	14	5983333	699275	canola	3				
203	Dews One	15	14	5983333	699275	canola	10				
238	Dews One	15	14	5983333	699275	canola	20	1912			
273	Dews One	15	14	5983333	699275	canola	75	1693	363	1330	0.79
308	Dews One	15	14	5983333	699275	canola	62	2073	660	1413	0.68
343	Dews One	15	14	5983333	699275	canola					
168	Hoyes North	14	6	5968418	698212	canola	7				
203	Hoyes North	14	6	5968418	698212	canola	5	174	44	130	0.75
238	Hoyes North	14	6	5968418	698212	canola	40	1262	156	1106	0.88
273	Hoyes North	14	6	5968418	698212	canola	100	3024	419	2605	0.86
308	Hoyes North	14	6	5968418	698212	canola	110	1775	455	1320	0.74
343	Hoyes North	14	6	5968418	698212	canola					
169	Southadels	14	21	5976048	686492	canola					
203	Southadels	14	21	5976048	686492	canola	13	380	54	326	0.86
238	Southadels	14	21	5976048	686492	canola	55	3763	219	3543	0.94
273	Southadels	14	21	5976048	686492	canola	120	2452	453	1999	0.82
308	Southadels	14	21	5976048	686492	canola	110	2099	646	1453	0.69
343	Southadels	14	21	5976048	686492	canola					
168	S'Side Front Corner	15	28	5980177	698095	canola	5				
203	S'Side Front Corner	15	28	5980177	698095	canola	17				
238	S'Side Front Corner	15	28	5980177	698095	canola	65	2210	272	1938	0.88
273	S'Side Front Corner	15	28	5980177	698095	canola	118	2279	451	1828	0.80

DOY	Field Name	Farm_n	Field_no	Northing	Easting	Crop Type	Plant Height [cm]	Wet Plant Weight [g/m2]	Dry Plant Weight [g/m2]	Plant Water [g/m2]	Plant Water [%]
308	S'Side Front Corner	15	28	5980177	698095	canola	87	1448	452	996	0.69
343	S'Side Front Corner	15	28	5980177	698095	canola					
168	Weir	14	11	5965214	695436	canola	6				
203	Weir	14	11	5965214	695436	canola	5	32	7	25	0.78
238	Weir	14	11	5965214	695436	canola	20	272	36	236	0.87
273	Weir	14	11	5965214	695436	canola	100	1482	241	1241	0.84
308	Weir	14	11	5965214	695436	canola	105	2289	621	1668	0.73
343	Weir	14	11	5965214	695436	canola					
203	Westalines	14	98	5976621	686604	canola	17	2010	112	1898	0.94
238	Westalines	14	98	5976621	686604	canola	60	3225	281	2943	0.91
273	Westalines	14	98	5976621	686604	canola	150	3885	615	3270	0.84
308	Westalines	14	98	5976621	686604	canola	140	2862	804	2058	0.72
168	Gilmours	14	10	5966410	694261	chickpea					
203	Gilmours	14	10	5966410	694261	chickpea	2				
238	Gilmours	14	10	5966410	694261	chickpea	15	40	11	29	0.72
273	Gilmours	14	10	5966410	694261	chickpea	20	365	78	287	0.79
308	Gilmours	14	10	5966410	694261	chickpea	40	1031	330	700	0.68
343	Gilmours	14	10	5966410	694261	chickpea	43	959	375	584	0.61
168	Hills	14	12	5965216	694665	chickpea					
203	Hills	14	12	5965216	694665	chickpea	1				
238	Hills	14	12	5965216	694665	chickpea	15	31	6	25	0.80
273	Hills	14	12	5965216	694665	chickpea	25	241	47	194	0.80
308	Hills	14	12	5965216	694665	chickpea	40	1232	279	953	0.77
343	Hills	14	12	5965216	694665	chickpea	45	1448	607	841	0.58
168	Mc Kews	14	13	5965077	695311	chickpea					
203	Mc Kews	14	13	5965077	695311	chickpea					
238	Mc Kews	14	13	5965077	695311	chickpea					
308	Mc Kews	14	13	5965077	695311	chickpea	25	748	192	556	0.74
343	Mc Kews	14	13	5965077	695311	chickpea	44	1406	648	758	0.54
273	McKews	14	13	5965077	695311	chickpea	15	97	23	73	0.76
168	Whites Back	15	36	5974173	699176	chickpea					
203	Whites Back	15	36	5974173	699176	chickpea	1				
238	Whites Back	15	36	5974173	699176	chickpea	10	136	32	104	0.76
273	Whites Back	15	36	5974173	699176	chickpea	20	452	98	354	0.78
308	Whites Back	15	36	5974173	699176	chickpea	35	977	287	690	0.71
343	Whites Back	15	36	5974173	699176	chickpea					
168	Woolshed	14	16	5976637	689291	chickpea					
203	Woolshed	14	16	5976637	689291	chickpea	5	15	4	11	0.73
238	Woolshed	14	16	5976637	689291	chickpea	15	52	13	39	0.75
273	Woolshed	14	16	5976637	689291	chickpea	25	205	49	156	0.76
308	Woolshed	14	16	5976637	689291	chickpea	40	934	287	647	0.69
343	Woolshed	14	16	5976637	689291	chickpea	45	1017	409	607	0.60
343	Woolshed AOI 1	14	16	5976780	688851	chickpea	35	360	347	13	0.04
168	Dews Two	15	15	5983153	699234	lentil	3				
203	Dews Two	15	15	5983153	699234	lentil	5				
238	Dews Two	15	15	5983153	699234	lentil	15	460	162	298	0.65

DOY	Field Name	Farm_n	Field_no	Northing	Easting	Crop Type	Plant Height [cm]	Wet Plant Weight [g/m2]	Dry Plant Weight [g/m2]	Plant Water [g/m2]	Plant Water [%]
273	Dews Two	15	15	5983153	699234	lentil	32	629	185	443	0.71
308	Dews Two	15	15	5983153	699234	lentil	40	1718	383	1334	0.78
343	Dews Two	15	15	5983153	699234	lentil	25	515	341	173	0.34
168	Fairview	14	15	5975234	689054	lentil					
203	Fairview	14	15	5975234	689054	lentil	1				
238	Fairview	14	15	5975234	689054	lentil	5	14	3	11	0.77
273	Fairview	14	15	5975234	689054	lentil	18	87	20	66	0.77
308	Fairview	14	15	5975234	689054	lentil	30	400	113	287	0.72
343	Fairview	14	15	5975234	689054	lentil	32	864	381	483	0.56
168	Fingerboard	14	4	5963529	698222	lentil					
203	Fingerboard	14	4	5963529	698222	lentil	4	14	2	12	0.86
238	Fingerboard	14	4	5963529	698222	lentil	15	44	11	33	0.75
273	Fingerboard	14	4	5963529	698222	lentil		656	129	527	0.80
308	Fingerboard	14	4	5963529	698222	lentil	25	1559	376	1183	0.76
343	Fingerboard	14	4	5963529	698222	lentil	25	323	190	133	0.41
168	Sams	15	34	5980332	699225	lentil	3				
203	Sams	15	34	5980327	700778	lentil	5				
238	Sams	15	34	5980327	700778	lentil		294	62	232	0.79
273	Sams	15	34	5980327	700778	lentil	33	1185	376	809	0.68
308	Sams	15	34	5980327	700778	lentil	35	772	407	365	0.47
343	Shed	14	3	5963569	697834	lentil	29	1219	633	586	0.48
343	Sams	15	34	5980327	700778	lentil					
168	Alphalane	14	17	5977389	688433	wheat	17				
203	Alphalane	14	17	5977389	688433	wheat	18	222	54	168	0.76
238	Alphalane	14	17	5977389	688433	wheat	45	1009	175	834	0.83
273	Alphalane	14	17	5977389	688433	wheat	60	1173	386	787	0.67
308	Alphalane	14	17	5977389	688433	wheat	75	966	484	481	0.50
343	Alphalane	14	17	5977389	688433	wheat					
168	Camp West	15	30	5974234	696976	wheat					
203	Camp West	15	30	5974234	696976	wheat	7	22			
238	Camp West	15	30	5974234	696976	wheat		419	106	313	0.75
273	Camp West	15	30	5974234	696976	wheat	57	1540	307	1234	0.80
308	Camp West	15	30	5974234	696976	wheat	70	1408	641	767	0.54
343	Camp West	15	30	5974234	696976	wheat					
168	Home Back West	15	12	5986276	701095	wheat					
203	Home Back West	15	12	5986276	701095	wheat	10				
238	Home Back West	15	12	5986276	701095	wheat	20	363	62	301	0.83
273	Home Back West	15	12	5986276	701095	wheat					
308	Home Back West	15	12	5986276	701095	wheat	72	1097	527	570	0.52
343	Home Back West	15	12	5986276	701095	wheat	64	473	442	30	0.06
168	Hoyes House	14	5	5968285	698207	wheat	7				
203	Hoyes House	14	5	5968285	698207	wheat	18	241	48	193	0.80
238	Hoyes House	14	5	5968285	698207	wheat	30	957	168	789	0.82
273	Hoyes House	14	5	5968285	698207	wheat	60	1745	466	1279	0.73
308	Hoyes House	14	5	5968285	698207	wheat	90	1092	537	554	0.51
343	Hoyes House	14	5	5968285	698207	wheat	76	821	623	198	0.24

DOY	Field Name	Farm_n	Field_no	Northing	Easting	Crop Type	Plant Height [cm]	Wet Plant Weight [g/m2]	Dry Plant Weight [g/m2]	Plant Water [g/m2]	Plant Water [%]
168	Jewes	14	14	5973705	690963	wheat	16				
203	Jewes	14	14	5973705	690963	wheat	22	452	95	357	0.79
238	Jewes	14	14	5973705	690963	wheat	45	1946	279	1667	0.86
273	Jewes	14	14	5973705	690963	wheat	65	1823	577	1246	0.68
308	Jewes	14	14	5973705	690963	wheat	80	1677	931	746	0.44
343	Jewes	14	14	5973705	690963	wheat	83	644	569	75	0.12
343	Jewes AOI 3	14	14	5974105	689535	wheat	77	637	559	78	0.12
343	Jewes AOI 4	14	14	5974070	690294	wheat	82				
168	Lunar	14	19	5976227	688214	wheat	10	138			
203	Lunar	14	19	5976227	688214	wheat	18	186	33	153	0.82
238	Lunar	14	19	5976227	688214	wheat	40	1151	171	980	0.85
273	Lunar	14	19	5976227	688214	wheat	80	1513	473	1040	0.69
308	Lunar	14	19	5976227	688214	wheat	75	1502	790	711	0.47
343	Lunar	14	19	5976227	688214	wheat	78	845	798	47	0.06
168	Lynas Back Corner	15	40	5986302	700890	wheat	15				
203	Lynas Back Corner	15	40	5985972	700878	wheat	15				
238	Lynas Back Corner	15	40	5985972	700878	wheat		1630	298	1332	0.82
273	Lynas Back Corner	15	40	5985972	700878	wheat	78	965	378	587	0.61
308	Lynas Back Corner	15	40	5985972	700878	wheat	72	1102	394	708	0.64
343	Lynas Back Corner	15	40	5985972	700878	wheat	72	653	643	10	0.02
203	Lynas West Road	15	37	5984071	700138	wheat	20	1046			
238	Lynas West Road	15	37	5984071	700138	wheat	45	1801	285	1516	0.84
273	Lynas West Road	15	37	5984071	700138	wheat					
308	Lynas West Road	15	37	5984071	700138	wheat	65	867	501	366	0.42
343	Lynas West Road	15	37	5984071	700138	wheat	57	629	549	80	0.13
168	North	14	18	5976690	688912	wheat	15				
203	North	14	18	5976690	688912	wheat	19	325	67	258	0.79
238	North	14	18	5976690	688912	wheat	40	1119	193	926	0.83
273	North	14	18	5976690	688912	wheat	60	1468	423	1044	0.71
308	North	14	18	5976690	688912	wheat	85	1788	961	827	0.46
343	North	14	18	5976690	688912	wheat	74	686	664	22	0.03
168	O'Donnell North	14	2	5963386	698195	wheat	11				
203	O'Donnell North	14	2	5963386	698195	wheat	18	79	20	59	0.75
238	O'Donnell North	14	2	5963386	698195	wheat	30	684	113	571	0.83
273	O'Donnell North	14	2	5963386	698195	wheat	50	1309	302	1007	0.77
308	O'Donnell North	14	2	5963386	698195	wheat	75	1467	687	780	0.53
343	O'Donnell North	14	2	5963386	698195	wheat	80	666	517	148	0.22
168	Timber West	14	20	5975363	688211	wheat	15	236			
203	Timber West	14	20	5975363	688211	wheat	20	439	84	355	0.81
238	Timber West	14	20	5975363	688211	wheat	35	1214	216	998	0.82
273	Timber West	14	20	5975363	688211	wheat	70	1655	494	1161	0.70
308	Timber West	14	20	5975363	688211	wheat		1547	753	794	0.51

DOY	Field Name	Soil Vol. Moisture [%]	ASW 0-100 cm [mm]	Band 1	Band 2	Band 3	NDVI	IR-R	IR/R	TVI	SAVI
168	Crofts West										
203	Crofts West	16.48		5.15	7.92	17.43	0.38	9.51	2.20	212.29	0.55
238	Crofts West	16.82		6.08	5.43	40.61	0.76	35.17	7.47	1819.80	1.13
273	Crofts West	2.60		6.08	4.35	38.48	0.80	34.13	8.84	1870.52	1.18
168	Lynas West House										
203	Lynas West House			5.67	5.51	28.41	0.68	22.90	5.16	1159.64	1.00
238	Lynas West House	8.24		4.78	3.78	44.70	0.84	40.92	11.84	2141.05	1.25
273	Lynas West House	0.72		5.94	5.07	32.08	0.73	27.01	6.33	1433.82	1.08
308	Lynas West House	2.63		9.09	10.52	20.84	0.33	10.32	1.98	379.89	0.49
343	Lynas West House	3.09									
168	Merrillees	34.87	103								
203	Merrillees	21.51	97	6.08	9.33	15.77	0.26	6.44	1.69	13.12	0.38
168	Adelines	20.70	91								
203	Adelines	9.00	89	8.89	9.53	31.06	0.53	21.53	3.26	1015.21	0.79
238	Adelines	5.68	105	6.96	6.29	41.72	0.74	35.43	6.63	1835.46	1.10
273	Adelines	0.61	68	7.85	8.44	34.85	0.61	26.40	4.13	1263.40	0.90
308	Adelines	1.22	62	9.66	11.75	26.00	0.38	14.25	2.21	513.86	0.56
343	Adelines	1.49	68								
168	Bourkes South	21.12									
203	Bourkes South	8.85		6.17	4.84	39.81	0.78	34.97	8.22	1874.11	1.16
238	Bourkes South	6.41		5.88	4.16	54.20	0.86	50.04	13.03	2665.72	1.28
273	Bourkes South	0.34		7.49	6.69	40.64	0.72	33.94	6.07	1772.43	1.06
308	Bourkes South	1.37		9.86	11.91	28.95	0.42	17.05	2.43	657.95	0.62
343	Bourkes South	2.33									
168	Dews One										
203	Dews One			6.93	8.49	28.83	0.55	20.34	3.40	868.75	0.81
238	Dews One	12.82		5.88	4.58	49.99	0.83	45.41	10.92	2394.14	1.24
273	Dews One	1.07		6.50	4.86	46.61	0.81	41.75	9.59	2243.19	1.20
308	Dews One	8.28		10.00	11.08	30.42	0.47	19.33	2.74	863.75	0.69
343	Dews One	8.20									
168	Hoyes North	29.27	92								
203	Hoyes North	25.98	94	6.08	7.92	22.04	0.47	14.13	2.78	532.08	0.70
238	Hoyes North	23.23	120	7.07	6.80	36.26	0.68	29.46	5.33	1498.03	1.01
273	Hoyes North	1.53	88	7.17	5.46	45.04	0.78	39.58	8.25	2141.46	1.16
308	Hoyes North	7.86	49	9.02	9.49	38.89	0.61	29.39	4.10	1425.08	0.90
343	Hoyes North	8.39	43								
169	Southadels		83								
203	Southadels	19.53	76	7.75	6.13	34.08	0.70	27.96	5.56	1552.29	1.03
238	Southadels	13.12	76	5.62	4.29	47.67	0.83	43.38	11.11	2295.33	1.24
273	Southadels	0.80	42	7.58	5.65	45.01	0.78	39.36	7.96	2151.46	1.15
308	Southadels	4.50	38	10.02	11.64	30.86	0.45	19.23	2.65	808.07	0.67
343	Southadels	4.12	64								
168	S'Side Front Corner										
203	S'Side Front Corner			6.17	6.75	27.94	0.61	21.19	4.14	1003.96	0.90
238	S'Side Front Corner	15.79		6.16	4.68	48.55	0.82	43.87	10.37	2333.42	1.22
273	S'Side Front Corner	1.07		6.95	6.23	41.94	0.74	35.71	6.73	1854.03	1.10

DOY	Field Name	Soil Vol. Moisture [%]	ASW 0-100 cm [mm]	Band 1	Band 2	Band 3	NDVI	IR-R	IR/R	TVI	SAVI
308	S'Side Front Corner	5.91		10.00	11.91	29.57	0.43	17.66	2.48	701.59	0.63
343	S'Side Front Corner	6.87									
168	Weir	31.92	61								
203	Weir	24.22	60	5.83	8.38	14.50	0.27	6.13	1.73	64.79	0.39
238	Weir	20.33	87	7.79	9.33	24.01	0.44	14.68	2.57	587.96	0.65
273	Weir	1.60	57	8.02	8.73	27.52	0.52	18.79	3.15	872.29	0.77
308	Weir	6.41	31	9.47	10.73	30.26	0.48	19.53	2.82	857.05	0.71
343	Weir	8.09	52								
203	Westalines	19.22	145	6.90	6.73	36.93	0.69	30.20	5.49	1525.73	1.03
238	Westalines	19.68	150	5.99	4.07	55.12	0.86	51.05	13.56	2735.13	1.28
273	Westalines	1.45	97	7.29	4.85	52.78	0.83	47.93	10.89	2628.75	1.24
308	Westalines	7.78	90	10.02	11.27	37.52	0.54	26.25	3.33	1193.75	0.80
168	Gilmours	28.42	108								
203	Gilmours	22.09	105	5.77	8.98	16.67	0.30	7.69	1.86	79.58	0.44
238	Gilmours	20.98	120	7.87	9.96	20.78	0.35	10.82	2.09	342.04	0.52
273	Gilmours	1.11	103	8.02	7.81	30.60	0.59	22.79	3.92	1159.38	0.88
308	Gilmours	7.13	58	7.20	6.75	39.34	0.71	32.59	5.83	1672.73	1.05
343	Gilmours	7.67	38								
168	Hills	32.78	70								
203	Hills	29.26	80	6.77	9.77	15.44	0.22	5.67	1.58	1.67	0.33
238	Hills	25.56	100	7.87	9.92	19.82	0.33	9.89	2.00	299.74	0.49
273	Hills	1.37	84	8.02	8.31	25.92	0.51	17.60	3.12	852.50	0.76
308	Hills	7.40	29	7.80	7.66	36.22	0.65	28.56	4.73	1441.70	0.97
343	Hills	8.74	14								
168	Mc Kews	38.50	84								
203	Mc Kews	26.51	98	7.71	10.06	17.38	0.27	7.31	1.73	141.98	0.39
238	Mc Kews	24.30	124	9.08	11.54	21.09	0.29	9.55	1.83	243.88	0.43
308	Mc Kews	7.97	66	8.26	9.20	32.41	0.56	23.20	3.52	1070.27	0.83
343	Mc Kews	8.35	29								
273	McKews	1.64	107	8.75	10.21	25.04	0.42	14.83	2.45	603.12	0.62
168	Whites Back	38.81									
203	Whites Back	28.84		8.61	11.16	16.91	0.20	5.75	1.52	46.04	0.30
238	Whites Back	20.14		9.03	10.97	20.43	0.30	9.46	1.86	288.03	0.44
273	Whites Back	1.53		8.63	8.56	29.26	0.55	20.71	3.42	1042.01	0.81
308	Whites Back	7.25		9.34	9.86	33.25	0.54	23.39	3.37	1119.66	0.80
343	Whites Back	7.02									
168	Woolshed	26.74	35								
203	Woolshed	22.77	39	8.61	11.39	18.77	0.24	7.39	1.65	106.04	0.36
238	Woolshed	22.92	64	8.21	9.26	21.29	0.39	12.03	2.30	501.32	0.58
273	Woolshed	0.84	44	7.71	7.65	30.75	0.60	23.10	4.02	1160.14	0.89
308	Woolshed	4.96		7.36	6.64	39.34	0.71	32.70	5.93	1704.32	1.06
343	Woolshed	10.15									
343	Woolshed AOI 1										
168	Dews Two										
203	Dews Two			6.94	10.19	19.28	0.31	9.09	1.89	145.94	0.46
238	Dews Two	15.64		6.61	6.93	27.38	0.60	20.45	3.95	991.12	0.88

DOY	Field Name	Soil Vol. Moisture [%]	ASW 0-100 cm [mm]	Band 1	Band 2	Band 3	NDVI	IR-R	IR/R	TVI	SAVI
273	Dews Two	1.14		6.39	5.49	31.21	0.70	25.72	5.69	1371.88	1.04
308	Dews Two	6.37		8.50	8.50	33.33	0.59	24.83	3.92	1241.67	0.88
343	Dews Two	9.04									
168	Fairview		67								
203	Fairview	26.85	89	7.67	9.98	17.21	0.27	7.23	1.72	141.77	0.39
238	Fairview	22.43	118	9.16	11.04	18.58	0.25	7.54	1.68	198.22	0.38
273	Fairview	1.22	115	9.78	11.13	22.57	0.34	11.44	2.03	444.24	0.50
308	Fairview	7.25	120	10.43	11.36	29.93	0.45	18.57	2.63	839.89	0.67
343	Fairview	7.13	112								
168	Fingerboard	32.58	114								
203	Fingerboard	24.26	121	7.00	8.40	15.44	0.30	7.04	1.84	219.48	0.43
238	Fingerboard	19.64	151	8.00	9.58	18.97	0.33	9.39	1.98	319.74	0.49
273	Fingerboard	1.34	118	8.29	7.63	32.04	0.62	24.42	4.20	1284.17	0.91
308	Fingerboard	7.67	63	8.46	7.42	43.80	0.71	36.39	5.91	1918.64	1.06
343	Fingerboard	9.08	47								
168	Sams										
203	Sams			7.47	10.99	23.93	0.37	12.94	2.18	312.40	0.55
238	Sams	10.57		6.46	6.39	31.93	0.67	25.54	4.99	1283.22	0.99
273	Sams	1.07		5.95	4.27	40.12	0.81	35.85	9.39	1952.01	1.20
308	Sams			7.50	9.33	28.58	0.51	19.25	3.06	788.33	0.75
343	Shed	11.82	52								
343	Sams	5.76									
168	Alphalane	29.94	72								
203	Alphalane	16.97	66	7.17	7.03	29.48	0.61	22.45	4.19	1135.26	0.91
238	Alphalane	21.63	75	4.54	3.88	35.97	0.81	32.09	9.27	1667.11	1.19
273	Alphalane	1.26	23	5.60	5.36	29.64	0.69	24.28	5.53	1236.32	1.03
308	Alphalane	5.61	6	8.20	8.93	20.98	0.40	12.05	2.35	533.18	0.59
343	Alphalane	6.52	23								
168	Camp West	40.62									
203	Camp West	26.47		6.18	8.39	29.86	0.56	21.48	3.56	864.17	0.83
238	Camp West	15.11		7.11	10.87	17.71	0.24	6.84	1.63	15.39	0.35
273	Camp West	0.84		9.08	10.46	25.49	0.42	15.03	2.44	620.76	0.62
308	Camp West	6.45		9.30	11.23	26.43	0.40	15.20	2.35	576.70	0.60
343	Camp West	7.36									
168	Home Back West										
203	Home Back West			6.09	8.39	16.69	0.33	8.30	1.99	197.40	0.49
238	Home Back West	11.75		6.58	6.82	31.24	0.64	24.42	4.58	1198.55	0.95
273	Home Back West	0.76		6.38	6.00	28.48	0.65	22.48	4.75	1160.24	0.96
308	Home Back West	4.92		8.58	10.33	23.17	0.38	12.83	2.24	475.42	0.57
343	Home Back West	4.88									
168	Hoyes House	28.85	71								
203	Hoyes House	23.00	75	5.15	5.81	24.65	0.62	18.83	4.24	878.33	0.91
238	Hoyes House	19.64	85	4.87	4.20	36.79	0.80	32.59	8.76	1693.36	1.18
273	Hoyes House	1.14	44	4.56	4.50	31.56	0.75	27.06	7.01	1359.06	1.11
308	Hoyes House	5.57	22	6.37	8.29	23.11	0.47	14.82	2.79	558.83	0.70
343	Hoyes House	7.21	34								

DOY	Field Name	Soil Vol. Moisture [%]	ASW 0-100 cm [mm]	Band 1	Band 2	Band 3	NDVI	IR-R	IR/R	TVI	SAVI
168	Jewes	28.16	102								
203	Jewes	20.29	95	4.44	2.25	31.17	0.87	28.92	13.85	1653.65	1.28
238	Jewes	13.54	90	3.87	2.74	41.86	0.88	39.12	15.29	2063.42	1.30
273	Jewes	1.26	38	4.39	3.44	33.85	0.82	30.40	9.83	1609.86	1.21
308	Jewes	4.20	22	6.23	7.07	21.66	0.51	14.59	3.06	649.66	0.75
343	Jewes	6.03	59								
343	Jewes AOI 3	0.31									
343	Jewes AOI 4	2.94									
168	Lunar	23.48	93								
203	Lunar	11.67	76	6.92	4.64	29.96	0.73	25.32	6.46	1482.86	1.08
238	Lunar	9.61	72	3.93	3.18	36.28	0.84	33.09	11.39	1725.86	1.24
273	Lunar	0.57	30	4.60	4.57	30.10	0.74	25.53	6.59	1279.03	1.09
308	Lunar	2.98	25	7.68	9.70	21.73	0.38	12.02	2.24	408.98	0.56
343	Lunar	2.78	88								
168	Lynas Back Corner										
203	Lynas Back Corner			5.43	3.04	37.20	0.85	34.16	12.23	1934.43	1.26
238	Lynas Back Corner	9.57		3.84	3.01	30.50	0.82	27.49	10.12	1453.09	1.21
273	Lynas Back Corner	0.65		5.23	5.21	22.72	0.63	17.51	4.36	877.67	0.92
308	Lynas Back Corner	2.63		7.67	9.25	18.42	0.33	9.17	1.99	307.92	0.49
343	Lynas Back Corner	2.56									
203	Lynas West Road			3.72	1.32	47.52	0.95	46.20	35.92	2537.50	1.40
238	Lynas West Road	14.49		3.74	2.51	40.61	0.88	38.09	16.16	2020.86	1.31
273	Lynas West Road	1.47		4.54	3.94	28.04	0.75	24.10	7.12	1262.60	1.11
308	Lynas West Road	5.26		6.50	7.75	18.02	0.40	10.27	2.33	394.89	0.59
343	Lynas West Road	6.37									
168	North	27.64	78								
203	North	22.43	77	6.94	6.58	31.97	0.66	25.39	4.86	1302.92	0.98
238	North	19.42	95	4.21	3.63	39.37	0.83	35.74	10.84	1841.84	1.23
273	North	0.84	58	5.00	4.51	31.63	0.75	27.11	7.01	1401.74	1.11
308	North	4.92	36	7.70	8.98	22.16	0.42	13.18	2.47	538.18	0.63
343	North	7.40	60								
168	O'Donnell North	38.28	101								
203	O'Donnell North	27.96	105	5.17	7.67	18.98	0.42	11.31	2.48	328.13	0.63
238	O'Donnell North	18.27	128	5.74	6.74	33.49	0.67	26.75	4.97	1242.50	0.99
273	O'Donnell North	1.11	93	5.08	4.96	33.42	0.74	28.46	6.74	1434.79	1.10
308	O'Donnell North	5.38	42	6.37	7.93	25.65	0.53	17.72	3.23	737.73	0.78
343	O'Donnell North	7.63	57								
168	Timber West	28.32	89								
203	Timber West	20.14	82	5.19	4.96	29.90	0.72	24.94	6.03	1268.65	1.06
238	Timber West	14.30	93	3.99	2.74	35.13	0.86	32.39	12.84	1738.49	1.27
273	Timber West	0.99	27	4.60	3.86	29.47	0.77	25.61	7.63	1350.49	1.14
308	Timber West	2.94	9	7.52	9.02	21.82	0.41	12.80	2.42	497.27	0.61

Appendix H: Pairwise Correlation Results for Fieldwork and Satellite Parameters

Variable	Variable	R Barley	Count	Signif Prob	R Canola	Count	Signif Prob	R Chickpeas	Count	Signif Prob	R Lentils	Count	Signif Prob	R Wheat
ASW 0-100 cm [mm]	Band 1		1		-0.51	20	0.0216254830	0.03	15	0.9292186907	0.05	8	0.9075761973	-0.48
ASW 0-100 cm [mm]	Band 2		1		-0.52	20	0.0188492262	0.42	15	0.1171121674	0.35	8	0.3895419977	-0.48
ASW 0-100 cm [mm]	Band 3		1		0.38	20	0.0958809875	-0.49	15	0.0649152124	-0.58	8	0.1288153095	0.56
ASW 0-100 cm [mm]	NDVI		1		0.47	20	0.0381499997	-0.45	15	0.0897433566	-0.49	8	0.2152486680	0.51
ASW 0-100 cm [mm]	DVI		1		0.43	20	0.0578122899	-0.49	15	0.0613190891	-0.59	8	0.1230609776	0.55
ASW 0-100 cm [mm]	RVI		1		0.47	20	0.0352327261	-0.51	15	0.0531148746	-0.62	8	0.1028713541	0.48
ASW 0-100 cm [mm]	TVI		1		0.42	20	0.0629753161	-0.49	15	0.0640019037	-0.57	8	0.1440526050	0.52
ASW 0-100 cm [mm]	SAVI		1		0.47	20	0.0385753714	-0.45	15	0.0891651496	-0.49	8	0.2136253875	0.51
Dried Green Biomass [g/m2]	Band 1	0.64	6	0.1708151839	0.62	29	0.0003336061	-0.27	15	0.3355060310	-0.22	13	0.4709302694	0.34
Dried Green Biomass [g/m2]	Band 2	0.08	6	0.8868837396	0.39	29	0.0350192160	-0.61	15	0.0160486646	-0.31	13	0.3054453904	0.38
Dried Green Biomass [g/m2]	Band 3	0.12	6	0.8256894686	0.18	29	0.3420052044	0.91	15	0.0000025753	0.64	13	0.0182111466	-0.40
Dried Green Biomass [g/m2]	NDVI	0.12	6	0.8152177407	-0.08	29	0.6814897280	0.79	15	0.0004079422	0.56	13	0.0465058635	-0.40
Dried Green Biomass [g/m2]	DVI	0.08	6	0.8739936833	0.06	29	0.7401505411	0.88	15	0.0000151259	0.62	13	0.0251057869	-0.41
Dried Green Biomass [g/m2]	RVI	0.07	6	0.8972932621	-0.07	29	0.7048513115	0.84	15	0.0001057833	0.48	13	0.0953350869	-0.34
Dried Green Biomass [g/m2]	TVI	0.15	6	0.7779871244	0.04	29	0.8545215266	0.85	15	0.0000578405	0.57	13	0.0437016411	-0.41
Dried Green Biomass [g/m2]	SAVI	0.12	6	0.8149755353	-0.08	29	0.6932954694	0.80	15	0.0003888607	0.56	13	0.0458496473	-0.40
Green Biomass [g/m2]	Band 1	0.29	6	0.5839897367	-0.02	30	0.9209366140	-0.24	15	0.3849475376	-0.13	13	0.6758166160	-0.13
Green Biomass [g/m2]	Band 2	-0.31	6	0.5510764310	-0.26	30	0.1570909484	-0.61	15	0.0149275466	-0.40	13	0.1769112969	-0.14
Green Biomass [g/m2]	Band 3	0.52	6	0.2905129687	0.67	30	0.0000535006	0.91	15	0.0000031328	0.82	13	0.0006793925	0.16
Green Biomass [g/m2]	NDVI	0.47	6	0.3410864852	0.49	30	0.0056221927	0.81	15	0.0002844150	0.69	13	0.0088244084	0.14
Green Biomass [g/m2]	DVI	0.49	6	0.3226272003	0.61	30	0.0003511793	0.88	15	0.0000163585	0.78	13	0.0014937990	0.16
Green Biomass [g/m2]	RVI	0.54	6	0.2673368339	0.53	30	0.0023687770	0.82	15	0.0001924224	0.60	13	0.0309825915	0.16
Green Biomass [g/m2]	TVI	0.53	6	0.2801378704	0.59	30	0.0006705898	0.85	15	0.0000511339	0.76	13	0.0027094365	0.15
Green Biomass [g/m2]	SAVI	0.48	6	0.3399949600	0.50	30	0.0053572462	0.81	15	0.0002716827	0.69	13	0.0085596550	0.14
Plant Height [cm]	Band 1	0.63	7	0.1255139603	0.46	31	0.0088915214	0.08	18	0.7382143247	0.00	14	0.9997768577	0.29
Plant Height [cm]	Band 2	0.04	7	0.9278367041	0.17	31	0.3605141097	-0.75	18	0.0003410493	-0.29	14	0.3078300975	0.34
Plant Height [cm]	Band 3	0.19	7	0.6832705712	0.35	31	0.0551742795	0.96	18	0.0000000006	0.58	14	0.0297603383	-0.38
Plant Height [cm]	NDVI	0.17	7	0.7166447156	0.12	31	0.5059886337	0.94	18	0.0000000121	0.57	14	0.0318610459	-0.36
Plant Height [cm]	DVI	0.15	7	0.7462616256	0.26	31	0.1657282619	0.95	18	0.0000000012	0.56	14	0.0378321974	-0.39
Plant Height [cm]	RVI	0.11	7	0.8120368010	0.10	31	0.5784832478	0.92	18	0.0000000972	0.42	14	0.1383939195	-0.32
Plant Height [cm]	TVI	0.21	7	0.6481845320	0.24	31	0.1939836635	0.95	18	0.0000000016	0.54	14	0.0460599054	-0.38
Plant Height [cm]	SAVI	0.17	7	0.7156945053	0.13	31	0.4958820851	0.94	18	0.0000000114	0.57	14	0.0316749529	-0.36
Plant Water [g/m2]	Band 1	0.10	6	0.8486698760	-0.17	29	0.3867816775	-0.23	15	0.4111999218	-0.08	13	0.8024820134	-0.41
Plant Water [g/m2]	Band 2	-0.45	6	0.3761006739	-0.40	29	0.0321959101	-0.61	15	0.0159715952	-0.41	13	0.1694580985	-0.40
Plant Water [g/m2]	Band 3	0.64	6	0.1687264300	0.73	29	0.0000061967	0.90	15	0.0000064269	0.82	13	0.0005382298	0.52
Plant Water [g/m2]	NDVI	0.58	6	0.2277726210	0.59	29	0.0007806757	0.80	15	0.0003245296	0.69	13	0.0088699154	0.45
Plant Water [g/m2]	DVI	0.62	6	0.1905805544	0.69	29	0.0000310988	0.87	15	0.0000273054	0.79	13	0.0012208927	0.51
Plant Water [g/m2]	RVI	0.69	6	0.1274201501	0.64	29	0.0001805696	0.80	15	0.0003192692	0.60	13	0.0307626218	0.56
Plant Water [g/m2]	TVI	0.64	6	0.1699439132	0.67	29	0.0000695042	0.85	15	0.0000721011	0.78	13	0.0017344453	0.48
Plant Water [g/m2]	SAVI	0.58	6	0.2265958157	0.59	29	0.0007393525	0.80	15	0.0003111417	0.69	13	0.0085933855	0.45
Plant Water Content [%]	Band 1	-0.67	6	0.1462001780	-0.72	29	0.0000130995	0.17	15	0.5477323678	0.18	13	0.5462331118	-0.57
Plant Water Content [%]	Band 2	-0.33	6	0.5198263231	-0.75	29	0.0000030032	0.17	15	0.5549431431	0.04	13	0.9027892902	-0.63
Plant Water Content [%]	Band 3	0.29	6	0.5827165800	0.46	29	0.0122198655	-0.42	15	0.1146662713	-0.18	13	0.5481223856	0.72
Plant Water Content [%]	NDVI	0.20	6	0.7089413660	0.63	29	0.0002354680	-0.27	15	0.3317840462	-0.20	13	0.5123941510	0.69
Plant Water Content [%]	DVI	0.30	6	0.5643860740	0.54	29	0.0022709224	-0.39	15	0.1506325214	-0.16	13	0.5904704648	0.73
Plant Water Content [%]	RVI	0.35	6	0.4913252210	0.60	29	0.0005842403	-0.41	15	0.1245021334	-0.13	13	0.6675701583	0.64

Appendix H: Pairwise Correlation Results for Fieldwork and Satellite Parameters

Variable	Variable	R Barley	Count	Signif Prob	R Canola	Count	Signif Prob	R Chickpeas	Count	Signif Prob	R Lentils	Count	Signif Prob	R Wheat
Plant Water Content [%]	TVI	0.23	6	0.6629850849	0.56	29	0.0014087303	-0.34	15	0.2101177064	-0.11	13	0.7263127718	0.72
Plant Water Content [%]	SAVI	0.20	6	0.7073604753	0.63	29	0.0002468456	-0.27	15	0.3281465839	-0.20	13	0.5122691158	0.69
Soil Vol. Moisture Content [%]	Band 1	-0.35	7	0.4378476591	-0.41	30	0.0236386968	-0.12	20	0.6103342155	-0.05	13	0.8724411325	-0.22
Soil Vol. Moisture Content [%]	Band 2	0.30	7	0.5190135729	-0.16	30	0.3894672970	0.68	20	0.0009887470	0.40	13	0.1775466482	-0.15
Soil Vol. Moisture Content [%]	Band 3	-0.36	7	0.4307778470	-0.24	30	0.2073600650	-0.81	20	0.0000169916	-0.74	13	0.0037712166	0.27
Soil Vol. Moisture Content [%]	NDVI	-0.43	7	0.3417652796	-0.10	30	0.5961360231	-0.86	20	0.0000010062	-0.72	13	0.0057276674	0.18
Soil Vol. Moisture Content [%]	DVI	-0.35	7	0.4385082291	-0.16	30	0.3995435995	-0.81	20	0.0000138896	-0.72	13	0.0057094878	0.25
Soil Vol. Moisture Content [%]	RVI	-0.35	7	0.4416957978	-0.02	30	0.9135297792	-0.75	20	0.0001523740	-0.63	13	0.0208353323	0.22
Soil Vol. Moisture Content [%]	TVI	-0.42	7	0.3528184205	-0.15	30	0.4190299322	-0.83	20	0.0000056505	-0.73	13	0.0045072989	0.21
Soil Vol. Moisture Content [%]	SAVI	-0.42	7	0.3424397310	-0.10	30	0.5889273882	-0.86	20	0.0000010324	-0.72	13	0.0056383072	0.18

R= Pearson Product Moment Coefficient

Variable	Variable	Count	Signif Prob
ASW 0-100 cm [mm]	Band 1	28	0.0089650049
ASW 0-100 cm [mm]	Band 2	28	0.0105871837
ASW 0-100 cm [mm]	Band 3	28	0.0020683555
ASW 0-100 cm [mm]	NDVI	28	0.0055022816
ASW 0-100 cm [mm]	DVI	28	0.0022153763
ASW 0-100 cm [mm]	RVI	28	0.0093997425
ASW 0-100 cm [mm]	TVI	28	0.0041493748
ASW 0-100 cm [mm]	SAVI	28	0.0054089162
Dried Green Biomass [g/m2]	Band 1	38	0.0347199489
Dried Green Biomass [g/m2]	Band 2	38	0.0176120803
Dried Green Biomass [g/m2]	Band 3	38	0.0139840273
Dried Green Biomass [g/m2]	NDVI	38	0.0129557969
Dried Green Biomass [g/m2]	DVI	38	0.0104876420
Dried Green Biomass [g/m2]	RVI	38	0.0343273430
Dried Green Biomass [g/m2]	TVI	38	0.0102492283
Dried Green Biomass [g/m2]	SAVI	38	0.0128571891
Green Biomass [g/m2]	Band 1	40	0.4122832630
Green Biomass [g/m2]	Band 2	40	0.3886777764
Green Biomass [g/m2]	Band 3	40	0.3373371973
Green Biomass [g/m2]	NDVI	40	0.3798731181
Green Biomass [g/m2]	DVI	40	0.3298845919
Green Biomass [g/m2]	RVI	40	0.3154869384
Green Biomass [g/m2]	TVI	40	0.3460477860
Green Biomass [g/m2]	SAVI	40	0.3784712578
Plant Height [cm]	Band 1	39	0.0726870253
Plant Height [cm]	Band 2	39	0.0333880810
Plant Height [cm]	Band 3	39	0.0171768361
Plant Height [cm]	NDVI	39	0.0240920997
Plant Height [cm]	DVI	39	0.0152588610
Plant Height [cm]	RVI	39	0.0501067099
Plant Height [cm]	TVI	39	0.0160021503
Plant Height [cm]	SAVI	39	0.0238421655
Plant Water [g/m2]	Band 1	38	0.0114535999
Plant Water [g/m2]	Band 2	38	0.0125259362
Plant Water [g/m2]	Band 3	38	0.0008160167
Plant Water [g/m2]	NDVI	38	0.0048519886
Plant Water [g/m2]	DVI	38	0.0011027770
Plant Water [g/m2]	RVI	38	0.0002924444
Plant Water [g/m2]	TVI	38	0.0023680054
Plant Water [g/m2]	SAVI	38	0.0047094176
Plant Water Content [%]	Band 1	38	0.0001955790
Plant Water Content [%]	Band 2	38	0.0000261830
Plant Water Content [%]	Band 3	38	0.0000002780
Plant Water Content [%]	NDVI	38	0.0000016091
Plant Water Content [%]	DVI	38	0.0000002130
Plant Water Content [%]	RVI	38	0.0000128594

Appendix H: Pairwise Correlation Results for Fieldwork and Satellite Parameters

Variable	Variable	Count	Signif Prob
Plant Water Content [%]	TVI	38	0.0000004494
Plant Water Content [%]	SAVI	38	0.0000015193
Soil Vol. Moisture Content [%]	Band 1	41	0.1605474967
Soil Vol. Moisture Content [%]	Band 2	41	0.3495528670
Soil Vol. Moisture Content [%]	Band 3	41	0.0837396973
Soil Vol. Moisture Content [%]	NDVI	41	0.2584390216
Soil Vol. Moisture Content [%]	DVI	41	0.1150257817
Soil Vol. Moisture Content [%]	RVI	41	0.1610755356
Soil Vol. Moisture Content [%]	TVI	41	0.1906560794
Soil Vol. Moisture Content [%]	SAVI	41	0.2552691662

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
62	canola	0.76	4.30	6.75	18.80	0.47	2.79	12.05	0.69	369.75	7.40	5.80	43.15	0.76	7.44	37.35	1.13	2019.50	6.00
63	canola	0.26	4.25	7.29	14.13	0.32	1.94	6.83	0.47	52.71	8.29	9.79	25.29	0.44	2.58	15.50	0.65	632.50	7.42
64	canola	0.81	4.36	6.75	17.82	0.45	2.64	11.07	0.66	326.25	7.21	5.82	39.46	0.74	6.78	33.64	1.10	1814.46	6.50
65	canola	0.53	4.31	6.69	17.50	0.45	2.62	10.81	0.66	315.00	7.63	6.38	41.06	0.73	6.44	34.69	1.09	1853.13	6.25
66	canola	0.37	4.00	7.20	14.20	0.33	1.97	7.00	0.48	46.00	8.15	9.00	24.30	0.46	2.70	15.30	0.68	684.25	7.30
67	canola	0.82	4.30	6.75	17.50	0.44	2.59	10.75	0.65	304.75	7.65	6.05	38.05	0.73	6.29	32.00	1.08	1752.00	6.10
68	canola	0.67	4.50	6.75	19.75	0.49	2.93	13.00	0.72	436.25	7.50	6.25	43.88	0.75	7.02	37.63	1.11	2000.00	6.00
69	canola	0.73	4.50	6.88	18.06	0.45	2.63	11.19	0.66	333.75	7.38	6.25	38.88	0.72	6.22	32.63	1.07	1738.13	6.13
70	canola	0.46	4.25	6.56	17.19	0.45	2.62	10.63	0.66	311.56	7.50	6.19	40.81	0.74	6.60	34.63	1.09	1855.94	6.00
71	canola	0.80	4.25	6.75	17.17	0.44	2.54	10.42	0.64	283.33	7.63	6.75	34.75	0.67	5.15	28.00	1.00	1483.13	6.08
107	canola	0.93	4.75	7.50	18.50	0.42	2.47	11.00	0.62	288.75	8.50	7.25	38.50	0.68	5.31	31.25	1.01	1681.25	5.25
108	canola	0.79	4.81	6.88	21.06	0.51	3.06	14.19	0.75	513.44	8.13	5.75	47.31	0.78	8.23	41.56	1.16	2303.75	5.25
109	canola	1.10	4.13	6.50	16.13	0.43	2.48	9.63	0.62	255.63	8.00	6.38	45.25	0.75	7.10	38.88	1.12	2098.13	5.00
110	canola	1.06	4.50	6.25	19.00	0.50	3.04	12.75	0.74	471.25	8.50	6.25	46.13	0.76	7.38	39.88	1.13	2207.50	5.75
111	canola	1.14	4.50	6.13	18.00	0.49	2.94	11.88	0.72	439.38	8.25	6.00	47.25	0.77	7.88	41.25	1.15	2276.25	5.13
112	canola	0.73	4.50	6.25	19.75	0.52	3.16	13.50	0.76	508.75	8.50	5.75	50.50	0.80	8.78	44.75	1.18	2498.75	5.25
113	canola	0.84	5.00	9.50	18.00	0.31	1.89	8.50	0.46	2.50	8.00	6.75	41.25	0.72	6.11	34.50	1.07	1843.75	5.25
114	canola	0.72	5.00	7.63	17.00	0.38	2.23	9.38	0.56	219.38	8.25	8.38	39.63	0.65	4.73	31.25	0.97	1550.63	5.25
115	canola	1.08	4.25	6.00	17.38	0.49	2.90	11.38	0.71	402.50	8.00	5.75	46.25	0.78	8.04	40.50	1.16	2238.75	5.25
144	canola	0.54	4.50	6.75	18.00	0.45	2.67	11.25	0.67	348.75	8.50	6.25	44.75	0.75	7.16	38.50	1.12	2138.75	5.25
145	canola	0.57	4.25	6.50	17.38	0.46	2.67	10.88	0.67	330.00	8.38	5.50	45.75	0.79	8.32	40.25	1.17	2285.63	5.25
146	canola	1.00	4.50	6.88	16.88	0.42	2.45	10.00	0.62	274.38	8.25	6.25	45.25	0.76	7.24	39.00	1.13	2140.00	5.50
147	canola	1.14	4.25	6.42	16.08	0.43	2.51	9.67	0.63	277.50	8.50	6.25	43.17	0.75	6.91	36.92	1.11	2059.59	5.25
148	canola	1.14	4.75	8.00	17.75	0.38	2.22	9.75	0.56	178.75	8.50	6.75	44.75	0.74	6.63	38.00	1.10	2066.25	5.75
149	canola	1.18	4.25	6.13	17.38	0.48	2.84	11.25	0.70	384.38	8.50	6.00	45.75	0.77	7.63	39.75	1.14	2225.00	5.25
150	canola	0.70	4.25	6.50	17.50	0.46	2.69	11.00	0.67	336.25	8.75	5.50	44.75	0.78	8.14	39.25	1.16	2271.25	5.25
151	canola	0.56	4.50	6.63	17.38	0.45	2.62	10.75	0.66	335.63	8.00	5.25	45.25	0.79	8.62	40.00	1.18	2261.25	5.25
153	canola	0.98	4.50	6.75	17.13	0.43	2.54	10.38	0.64	305.00	8.50	6.00	46.00	0.77	7.67	40.00	1.14	2237.50	5.25
154	canola	0.60	5.00	7.08	18.67	0.45	2.64	11.58	0.66	381.25	8.50	6.25	40.50	0.73	6.48	34.25	1.09	1926.25	5.25
155	canola	0.62	5.00	7.00	18.38	0.45	2.63	11.38	0.66	378.75	8.25	6.50	40.50	0.72	6.23	34.00	1.07	1866.25	5.25
156	canola	0.59	4.50	6.88	15.25	0.38	2.22	8.38	0.56	193.13	8.00	6.88	33.88	0.66	4.93	27.00	0.98	1456.88	5.88
157	canola	0.62	4.50	6.75	16.50	0.42	2.44	9.75	0.62	273.75	8.00	6.25	37.25	0.71	5.96	31.00	1.06	1716.25	5.75
158	canola	0.61	5.00	7.13	18.13	0.44	2.54	11.00	0.64	348.13	8.50	6.50	41.75	0.73	6.42	35.25	1.08	1952.50	5.25
159	canola	1.00	4.25	6.25	17.75	0.48	2.84	11.50	0.70	385.00	8.00	5.50	47.25	0.79	8.59	41.75	1.18	2325.00	5.25
170	canola	0.57	3.25	6.75	14.50	0.36	2.15	7.75	0.53	55.00	8.13	9.50	27.25	0.48	2.87	17.75	0.71	756.88	5.88
171	canola	0.22	2.38	3.94	12.25	0.51	3.11	8.31	0.75	267.19	6.75	6.50	19.75	0.50	3.04	13.25	0.74	686.25	5.50
172	canola	0.08	2.00	3.67	7.00	0.31	1.91	3.33	0.45	8.33	6.58	6.50	13.83	0.36	2.13	7.33	0.53	374.58	6.25
173	canola	0.20	3.75	6.25	10.50	0.25	1.68	4.25	0.37	25.00	8.00	10.00	16.75	0.25	1.68	6.75	0.37	147.50	7.75
174	canola	0.44	4.00	7.63	15.75	0.35	2.07	8.13	0.51	61.88	9.75	11.50	27.50	0.41	2.39	16.00	0.61	633.75	6.25
175	canola	0.30	3.50	5.88	10.00	0.26	1.70	4.13	0.38	19.38	8.75	10.38	20.25	0.32	1.95	9.88	0.48	339.38	7.50
176	canola	0.06	4.25	7.25	12.63	0.27	1.74	5.38	0.40	16.25	8.25	9.50	19.00	0.33	2.00	9.50	0.49	356.25	7.75
177	canola	0.19	4.00	7.00	12.25	0.27	1.75	5.25	0.40	22.50	8.00	9.25	21.75	0.40	2.35	12.50	0.60	506.25	6.75
178	canola	0.10	4.25	7.25	11.75	0.24	1.62	4.50	0.35	60.00	8.00	10.75	17.50	0.24	1.63	6.75	0.35	76.25	8.00
179	canola	0.24	4.00	7.13	12.00	0.25	1.68	4.88	0.37	53.13	8.00	10.00	19.25	0.32	1.93	9.25	0.47	272.50	7.25
180	canola	0.21	3.75	6.75	11.25	0.25	1.67	4.50	0.36	60.00	8.00	9.75	18.00	0.30	1.85	8.25	0.44	246.25	7.75
181	canola	0.25	4.25	7.50	12.75	0.26	1.70	5.25	0.38	46.25	8.38	10.38	19.38	0.30	1.87	9.00	0.45	260.00	7.38
182	canola	0.48	4.08	7.25	12.58	0.27	1.74	5.33	0.39	34.17	8.00	10.00	21.67	0.37	2.17	11.67	0.54	393.33	7.50
183	canola	0.69	3.38	6.88	11.38	0.25	1.65	4.50	0.36	107.50	8.00	10.13	23.50	0.40	2.32	13.38	0.59	466.88	6.75

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
184	canola	0.22	4.00	7.00	11.75	0.25	1.68	4.75	0.37	47.50	8.00	9.75	17.75	0.29	1.82	8.00	0.43	233.75	7.00
221	canola	0.57	6.25	12.00	21.50	0.28	1.79	9.50	0.42	71.25	9.50	8.75	39.75	0.64	4.54	31.00	0.95	1621.25	5.75
222	canola	0.67	6.75	12.25	23.25	0.31	1.90	11.00	0.46	27.50	8.50	8.75	40.50	0.64	4.63	31.75	0.96	1563.75	5.25
223	canola	0.88	4.00	6.25	16.50	0.45	2.64	10.25	0.66	298.75	8.00	5.25	46.00	0.80	8.76	40.75	1.18	2298.75	5.25
224	canola	0.83	4.25	6.75	17.00	0.43	2.52	10.25	0.63	275.00	8.00	6.25	44.00	0.75	7.04	37.75	1.12	2053.75	5.25
225	canola	0.78	4.25	6.75	16.25	0.41	2.41	9.50	0.61	237.50	8.50	6.25	42.25	0.74	6.76	36.00	1.10	2013.75	5.25
300	canola	0.71	4.33	6.58	17.58	0.46	2.67	11.00	0.67	336.25	7.50	6.25	41.83	0.74	6.69	35.58	1.10	1897.91	6.00
301	canola	0.75	4.42	6.83	18.42	0.46	2.70	11.58	0.67	349.59	7.33	5.92	40.83	0.75	6.90	34.92	1.11	1880.41	5.92
302	canola	0.58	4.50	6.63	19.75	0.50	2.98	13.13	0.73	454.38	7.38	5.88	44.88	0.77	7.64	39.00	1.14	2092.50	6.00
303	canola	1.11	4.25	7.13	15.31	0.36	2.15	8.19	0.54	136.25	8.38	7.75	28.38	0.57	3.66	20.63	0.84	1090.63	7.13
304	canola	0.81	4.25	7.00	18.50	0.45	2.64	11.50	0.66	313.75	7.50	6.25	44.50	0.75	7.12	38.25	1.12	2031.25	6.00
305	canola	0.82	4.50	6.75	20.38	0.50	3.02	13.63	0.74	467.50	7.88	5.25	46.88	0.80	8.93	41.63	1.19	2330.63	6.00
306	canola	0.74	4.33	6.75	18.58	0.47	2.75	11.83	0.69	362.08	7.33	6.33	42.42	0.74	6.70	36.08	1.10	1899.17	6.00
307	canola	0.36	4.25	6.75	16.08	0.41	2.38	9.33	0.60	229.17	8.00	7.75	33.42	0.62	4.31	25.67	0.92	1307.09	6.33
308	canola	0.80	4.25	6.75	18.67	0.47	2.77	11.92	0.69	358.33	7.75	7.25	38.25	0.68	5.28	31.00	1.01	1597.50	6.75
309	canola	0.33	3.75	6.25	16.25	0.44	2.60	10.00	0.65	262.50	7.00	6.75	38.75	0.70	5.74	32.00	1.04	1623.75	6.75
310	canola	0.73	4.25	6.75	16.83	0.43	2.49	10.08	0.63	266.67	7.50	5.92	39.75	0.74	6.72	33.83	1.10	1842.08	6.25
311	canola	0.67	4.25	6.88	16.13	0.40	2.35	9.25	0.59	213.13	7.50	8.00	36.50	0.64	4.56	28.50	0.95	1377.50	6.25
312	canola	0.81	4.50	6.50	19.17	0.49	2.95	12.67	0.73	443.33	7.50	5.42	43.67	0.78	8.06	38.25	1.16	2110.42	5.92
313	canola	0.59	4.50	6.67	19.17	0.48	2.87	12.50	0.71	419.17	7.33	5.58	44.75	0.78	8.01	39.17	1.16	2124.58	6.00
314	canola	0.59	4.50	6.75	17.50	0.44	2.59	10.75	0.65	323.75	7.50	6.50	40.00	0.72	6.15	33.50	1.07	1770.00	6.50
315	canola	0.22	4.13	6.75	14.13	0.35	2.09	7.38	0.52	119.38	7.88	8.50	31.13	0.57	3.66	22.63	0.85	1071.88	7.38
316	canola	0.79	4.25	6.75	18.25	0.46	2.70	11.50	0.68	337.50	7.50	6.25	42.50	0.74	6.80	36.25	1.10	1931.25	6.00
434	canola	0.61	5.25	7.13	18.88	0.45	2.65	11.75	0.67	409.38	8.50	6.25	42.00	0.74	6.72	35.75	1.10	2001.25	5.25
435	canola	0.58	4.50	7.00	15.75	0.38	2.25	8.75	0.56	200.00	8.00	6.88	36.63	0.68	5.33	29.75	1.01	1594.38	5.75
436	canola	0.59	4.25	6.50	14.25	0.37	2.19	7.75	0.55	173.75	8.00	6.75	32.00	0.65	4.74	25.25	0.96	1381.25	5.75
437	canola	1.14	4.50	6.69	16.81	0.43	2.51	10.13	0.63	298.44	8.38	6.50	43.63	0.74	6.71	37.13	1.10	2034.38	5.25
438	canola	0.61	4.33	6.67	16.58	0.43	2.49	9.92	0.63	274.16	8.33	5.75	45.50	0.78	7.91	39.75	1.15	2232.92	5.25
439	canola	0.48	5.50	10.25	17.50	0.26	1.71	7.25	0.38	88.75	8.50	8.75	35.25	0.60	4.03	26.50	0.89	1301.25	5.75
440	canola	0.71	4.50	7.00	17.25	0.42	2.46	10.25	0.62	275.00	8.33	6.75	43.58	0.73	6.46	36.83	1.09	1992.08	5.75
441	canola	0.72	4.50	7.00	16.00	0.39	2.29	9.00	0.57	212.50	8.00	6.75	40.13	0.71	5.94	33.38	1.06	1787.50	5.00
442	canola	1.45	4.50	6.75	16.63	0.42	2.46	9.88	0.62	280.00	8.25	5.63	45.38	0.78	8.07	39.75	1.16	2236.88	5.25
443	canola	0.66	4.38	6.88	16.38	0.41	2.38	9.50	0.60	237.50	8.50	6.75	41.50	0.72	6.15	34.75	1.07	1903.75	5.25
444	canola	1.02	4.50	7.00	17.00	0.42	2.43	10.00	0.61	262.50	8.50	6.75	44.25	0.74	6.56	37.50	1.09	2041.25	5.25
445	canola	0.56	5.00	7.25	18.25	0.43	2.52	11.00	0.63	336.25	8.00	6.75	41.25	0.72	6.11	34.50	1.07	1843.75	5.75
458	canola	0.24	4.00	7.42	12.75	0.26	1.72	5.33	0.39	57.92	8.50	10.25	21.50	0.35	2.10	11.25	0.52	396.25	7.25
459	canola	0.23	4.25	7.50	12.75	0.26	1.70	5.25	0.38	46.25	8.38	10.00	19.38	0.32	1.94	9.38	0.47	314.38	7.50
461	canola	0.45	4.00	7.25	12.50	0.27	1.72	5.25	0.39	46.25	8.50	9.75	21.00	0.37	2.15	11.25	0.54	443.75	7.50
462	canola	0.22	4.25	7.50	13.00	0.27	1.73	5.50	0.39	33.75	8.00	9.75	20.00	0.34	2.05	10.25	0.51	346.25	7.75
463	canola	0.11	4.17	7.25	12.83	0.28	1.77	5.58	0.41	13.75	8.17	9.75	20.25	0.35	2.08	10.50	0.52	374.58	7.67
464	canola	0.16	3.63	6.75	11.50	0.26	1.70	4.75	0.38	59.38	8.00	9.25	20.75	0.38	2.24	11.50	0.57	456.25	7.00
465	canola	0.73	3.00	5.69	13.31	0.40	2.34	7.63	0.59	125.94	7.94	8.50	29.00	0.55	3.41	20.50	0.81	971.56	6.00
466	canola	0.45	3.88	7.13	12.13	0.26	1.70	5.00	0.38	58.75	8.25	9.75	22.00	0.39	2.26	12.25	0.57	470.00	7.13
467	canola	0.50	2.63	5.63	9.88	0.27	1.76	4.25	0.40	72.50	8.00	10.13	19.00	0.30	1.88	8.88	0.45	241.88	7.50
468	canola	0.26	2.88	6.00	9.88	0.24	1.65	3.88	0.35	103.13	8.00	9.75	17.25	0.28	1.77	7.50	0.41	208.75	7.75
470	canola	0.20	4.50	7.50	12.50	0.25	1.67	5.00	0.37	35.00	8.50	9.75	18.75	0.32	1.92	9.00	0.47	331.25	8.00
471	canola	0.21	4.00	7.25	12.25	0.26	1.69	5.00	0.38	58.75	8.00	9.25	24.50	0.45	2.65	15.25	0.67	643.75	7.75
472	canola	0.24	3.63	6.63	10.88	0.24	1.64	4.25	0.35	72.50	8.50	10.00	17.75	0.28	1.78	7.75	0.41	245.00	7.75

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
473	canola	0.47	2.63	5.88	12.50	0.36	2.13	6.63	0.53	22.50	7.00	8.75	25.63	0.49	2.93	16.88	0.73	677.50	6.38
474	canola	0.47	2.88	6.75	14.38	0.36	2.13	7.63	0.53	13.13	8.25	10.00	27.63	0.47	2.76	17.63	0.69	715.00	6.00
475	canola	0.52	3.13	6.38	12.63	0.33	1.98	6.25	0.48	3.75	8.50	10.13	25.88	0.44	2.56	15.75	0.65	633.13	6.00
476	canola	0.19	4.00	6.31	11.25	0.28	1.78	4.94	0.41	27.19	8.19	9.25	18.00	0.32	1.95	8.75	0.47	336.56	8.44
477	canola	0.04	2.00	3.75	7.25	0.32	1.93	3.50	0.46	8.75	6.25	6.50	14.33	0.38	2.21	7.83	0.55	367.92	5.75
478	canola	0.03	2.00	3.50	7.13	0.34	2.04	3.63	0.49	38.75	5.63	6.25	13.50	0.37	2.16	7.25	0.54	303.13	5.75
479	canola	0.22	3.75	6.38	12.25	0.32	1.92	5.88	0.46	44.38	8.00	9.25	22.50	0.42	2.43	13.25	0.62	543.75	7.00
480	canola	0.27	3.75	6.50	11.25	0.27	1.73	4.75	0.39	23.75	8.00	10.00	18.75	0.30	1.88	8.75	0.45	247.50	7.00
481	canola	0.46	2.88	6.75	14.38	0.36	2.13	7.63	0.53	13.13	8.25	9.25	26.75	0.49	2.89	17.50	0.72	780.00	6.00
482	canola	0.47	3.13	5.75	13.38	0.40	2.33	7.63	0.58	131.88	7.50	8.00	27.25	0.55	3.41	19.25	0.81	915.00	6.00
483	canola	0.53	3.25	6.50	12.50	0.32	1.92	6.00	0.46	8.75	8.25	10.00	24.50	0.42	2.45	14.50	0.62	558.75	6.00
484	canola	0.26	2.50	4.00	9.50	0.41	2.38	5.50	0.59	132.50	6.00	6.50	14.75	0.39	2.27	8.25	0.57	365.00	5.75
485	canola	0.01	2.25	3.75	7.25	0.32	1.93	3.50	0.46	32.50	7.00	6.50	13.50	0.35	2.08	7.00	0.51	397.50	6.50
486	canola	0.26	3.00	6.25	11.88	0.31	1.90	5.63	0.45	27.50	8.00	9.63	27.50	0.48	2.86	17.88	0.71	739.38	6.50
487	canola	0.18	2.00	3.25	7.75	0.41	2.38	4.50	0.59	106.25	7.00	6.50	15.25	0.40	2.35	8.75	0.59	485.00	6.50
488	canola	0.19	4.25	7.25	12.75	0.28	1.76	5.50	0.40	10.00	8.50	10.13	19.00	0.30	1.88	8.88	0.45	289.38	7.75
489	canola	0.55	2.13	4.75	17.25	0.57	3.63	12.50	0.83	375.63	5.50	7.19	29.81	0.61	4.15	22.63	0.91	970.94	5.50
490	canola	0.27	4.13	6.88	11.50	0.25	1.67	4.63	0.37	30.00	10.13	11.00	21.50	0.32	1.95	10.50	0.48	441.88	8.00
498	canola	0.93	4.50	6.25	20.75	0.54	3.32	14.50	0.79	558.75	8.00	6.75	51.50	0.77	7.63	44.75	1.14	2356.25	5.25
499	canola	0.79	5.63	10.38	18.25	0.28	1.76	7.88	0.41	57.50	10.13	9.50	33.50	0.56	3.53	24.00	0.83	1259.38	6.25
500	canola	0.79	4.50	7.75	16.25	0.35	2.10	8.50	0.52	116.25	8.00	6.75	43.75	0.73	6.48	37.00	1.09	1968.75	5.25
501	canola	0.95	4.42	6.17	17.75	0.48	2.88	11.58	0.71	412.92	8.33	6.58	45.58	0.75	6.92	39.00	1.11	2116.25	5.75
502	canola	1.06	4.50	6.25	18.63	0.50	2.98	12.38	0.73	452.50	8.25	6.75	46.50	0.75	6.89	39.75	1.11	2130.00	5.50
503	canola	1.05	4.67	6.33	19.50	0.51	3.08	13.17	0.75	500.00	8.17	5.25	47.58	0.80	9.06	42.33	1.19	2393.75	5.33
504	canola	0.85	4.25	6.04	17.58	0.49	2.91	11.54	0.72	406.87	8.50	6.25	44.21	0.75	7.07	37.96	1.12	2111.66	5.42
505	canola	0.76	4.44	7.69	17.19	0.38	2.24	9.50	0.56	166.25	8.06	6.75	42.75	0.73	6.33	36.00	1.08	1924.69	5.25
506	canola	0.93	4.25	6.25	16.25	0.44	2.60	10.00	0.65	310.00	8.00	6.25	45.25	0.76	7.24	39.00	1.13	2116.25	5.25
507	canola	0.76	5.55	8.30	22.65	0.46	2.73	14.35	0.68	456.25	8.00	5.65	47.30	0.79	8.37	41.65	1.17	2305.75	5.25
508	canola	0.95	4.92	6.58	21.75	0.54	3.30	15.17	0.79	600.00	8.33	4.92	52.42	0.83	10.66	47.50	1.23	2699.59	4.92
509	canola	1.03	4.00	5.88	16.38	0.47	2.79	10.50	0.69	346.88	8.00	5.75	43.63	0.77	7.59	37.88	1.14	2107.50	5.50
510	canola	1.00	4.50	6.25	20.65	0.54	3.30	14.40	0.79	553.75	8.20	5.35	49.35	0.80	9.22	44.00	1.20	2470.75	5.20
511	canola	1.05	4.33	6.08	19.58	0.53	3.22	13.50	0.77	508.75	8.17	5.42	47.75	0.80	8.82	42.33	1.18	2377.92	5.42
512	canola	0.86	5.17	8.25	21.25	0.44	2.58	13.00	0.65	357.08	8.00	6.58	45.17	0.75	6.86	38.58	1.11	2063.76	5.25
513	canola	0.68	5.50	8.25	21.75	0.45	2.64	13.50	0.66	413.75	8.00	6.75	42.25	0.72	6.26	35.50	1.08	1893.75	5.25
514	canola	1.11	4.00	6.25	16.13	0.44	2.58	9.88	0.65	280.00	8.25	5.00	45.50	0.80	9.10	40.50	1.19	2333.75	5.25
515	canola	0.55	6.38	12.25	22.00	0.28	1.80	9.75	0.42	70.63	9.50	8.50	39.75	0.65	4.68	31.25	0.96	1657.50	5.25
516	canola	0.96	5.00	8.17	16.42	0.34	2.01	8.25	0.49	111.67	8.17	6.92	39.25	0.70	5.67	32.33	1.04	1735.42	5.25
517	canola	0.90	5.00	8.25	15.25	0.30	1.85	7.00	0.44	41.25	9.50	7.25	32.75	0.64	4.52	25.50	0.94	1488.75	5.75
518	canola	0.90	5.13	9.25	18.63	0.34	2.01	9.38	0.50	76.88	8.00	7.00	38.63	0.69	5.52	31.63	1.03	1676.25	5.25
519	canola	0.58	5.38	10.00	17.13	0.26	1.71	7.13	0.39	83.13	9.75	8.38	35.63	0.62	4.25	27.25	0.92	1493.13	5.75
520	canola	0.61	6.19	11.44	18.75	0.24	1.64	7.31	0.36	133.13	10.56	11.19	32.50	0.49	2.91	21.31	0.72	1006.25	6.38
521	canola	0.79	4.00	5.88	17.88	0.51	3.04	12.00	0.74	421.88	8.50	6.25	48.00	0.77	7.68	41.75	1.14	2301.25	5.50
522	canola	0.96	4.00	6.00	16.25	0.46	2.71	10.25	0.68	322.50	8.25	5.00	47.63	0.81	9.53	42.63	1.20	2440.00	5.25
523	canola	1.17	4.25	5.75	19.88	0.55	3.46	14.13	0.81	563.75	8.50	5.25	48.13	0.80	9.17	42.88	1.19	2452.50	5.38
524	canola	1.17	4.13	6.00	18.13	0.50	3.02	12.13	0.74	428.13	8.00	6.00	48.63	0.78	8.10	42.63	1.16	2321.25	5.75
525	canola	0.87	5.50	9.88	18.75	0.31	1.90	8.88	0.46	28.13	9.00	7.00	40.13	0.70	5.73	33.13	1.04	1846.25	5.25
526	canola	0.99	4.50	6.00	19.00	0.52	3.17	13.00	0.76	507.50	8.00	5.25	47.75	0.80	9.10	42.50	1.19	2386.25	5.00
527	canola	1.13	4.00	6.50	16.00	0.42	2.46	9.50	0.62	237.50	8.00	5.25	45.25	0.79	8.62	40.00	1.18	2261.25	5.00

Appendix I: Yield Map and Satellite Parameter Database

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
528	canola	0.95	4.63	6.50	21.00	0.53	3.23	14.50	0.78	546.88	8.25	4.75	52.38	0.83	11.03	47.63	1.24	2713.75	5.25
529	canola	0.78	7.00	13.25	23.50	0.28	1.77	10.25	0.41	81.25	9.50	10.25	36.75	0.56	3.59	26.50	0.84	1253.75	5.75
530	canola	0.97	4.25	6.25	19.25	0.51	3.08	13.00	0.75	460.00	8.00	6.00	47.25	0.77	7.88	41.25	1.15	2252.50	5.75
531	canola	1.09	4.50	6.42	19.33	0.50	3.01	12.92	0.74	463.75	8.50	6.00	47.58	0.78	7.93	41.58	1.15	2316.66	5.00
532	canola	1.01	4.00	5.50	17.75	0.53	3.23	12.25	0.77	470.00	8.50	6.25	47.25	0.77	7.56	41.00	1.14	2263.75	5.25
533	canola	0.87	5.00	7.00	19.25	0.47	2.75	12.25	0.69	422.50	8.00	5.25	49.00	0.81	9.33	43.75	1.20	2448.75	5.25
534	canola	0.81	5.50	9.33	17.58	0.31	1.88	8.25	0.45	48.33	8.50	8.67	35.83	0.61	4.13	27.17	0.91	1342.49	5.75
535	canola	0.96	5.40	9.30	19.65	0.36	2.11	10.35	0.53	147.00	8.40	6.55	42.60	0.73	6.50	36.05	1.09	1978.25	5.35
536	canola	0.78	4.75	7.50	18.50	0.42	2.47	11.00	0.62	288.75	8.50	6.75	47.00	0.75	6.96	40.25	1.11	2178.75	5.25
537	canola		4.50	7.25	17.00	0.40	2.34	9.75	0.59	226.25	8.50	6.25	44.00	0.75	7.04	37.75	1.12	2101.25	5.25
538	canola	0.78	4.25	6.75	17.44	0.44	2.58	10.69	0.65	296.88	8.06	6.00	46.56	0.77	7.76	40.56	1.15	2224.06	5.25
539	canola	0.79	4.50	6.75	17.75	0.45	2.63	11.00	0.66	336.25	8.00	5.25	47.00	0.80	8.95	41.75	1.19	2348.75	5.25
540	canola	0.85	6.63	10.88	23.50	0.37	2.16	12.63	0.54	227.50	8.50	6.50	42.63	0.74	6.56	36.13	1.09	1996.25	5.25
541	canola	1.08	4.50	6.00	19.13	0.52	3.19	13.13	0.77	513.75	8.50	5.25	47.63	0.80	9.07	42.38	1.19	2427.50	5.75
542	canola	1.15	4.50	6.50	19.13	0.49	2.94	12.63	0.72	441.25	9.00	6.75	46.50	0.75	6.89	39.75	1.11	2201.25	5.38
543	canola	0.84	5.75	10.25	19.75	0.32	1.93	9.50	0.47	47.50	9.50	8.25	40.50	0.66	4.91	32.25	0.98	1731.25	5.75
544	canola	0.76	5.75	10.50	21.25	0.34	2.02	10.75	0.50	86.25	8.50	6.75	44.00	0.73	6.52	37.25	1.09	2028.75	5.25
545	canola	0.72	5.25	8.50	18.25	0.36	2.15	9.75	0.54	178.75	9.17	6.75	43.42	0.73	6.43	36.67	1.09	2062.92	5.25
546	canola	0.69	5.50	8.25	21.75	0.45	2.64	13.50	0.66	413.75	8.00	6.75	45.25	0.74	6.70	38.50	1.10	2043.75	5.25
547	canola	1.04	4.50	6.00	18.00	0.50	3.00	12.00	0.73	457.50	8.00	6.75	46.25	0.75	6.85	39.50	1.11	2093.75	5.25
571	canola	0.52	4.00	7.25	13.25	0.29	1.83	6.00	0.43	8.75	8.00	10.25	24.00	0.40	2.34	13.75	0.59	473.75	7.25
20	chickpeas	0.63	3.38	6.06	10.44	0.27	1.72	4.38	0.39	36.56	8.38	10.00	18.19	0.29	1.82	8.19	0.43	255.00	7.69
21	chickpeas	0.35	3.19	5.75	9.94	0.27	1.73	4.19	0.39	34.06	8.00	9.75	18.06	0.30	1.85	8.31	0.44	249.38	7.38
22	chickpeas	0.34	3.33	6.25	10.83	0.27	1.73	4.58	0.39	47.92	9.00	10.38	18.96	0.29	1.83	8.58	0.43	298.54	8.13
23	chickpeas	0.54	3.44	6.25	10.94	0.27	1.75	4.69	0.40	32.81	8.50	10.31	18.25	0.28	1.77	7.94	0.41	224.69	8.13
24	chickpeas	0.61	3.33	6.50	10.83	0.25	1.67	4.33	0.36	84.17	8.50	9.75	18.75	0.32	1.92	9.00	0.47	331.25	7.75
25	chickpeas	0.28	3.21	5.58	9.67	0.27	1.73	4.08	0.39	21.46	8.25	9.08	16.75	0.30	1.84	7.67	0.44	304.17	7.54
26	chickpeas	0.44	3.13	6.06	10.38	0.26	1.71	4.31	0.38	63.44	8.13	9.94	18.44	0.30	1.86	8.50	0.44	252.81	7.75
27	chickpeas	0.46	3.25	6.38	10.81	0.26	1.70	4.44	0.38	75.00	8.00	10.69	18.94	0.28	1.77	8.25	0.41	157.19	7.63
28	chickpeas	0.56	2.75	6.33	10.75	0.26	1.70	4.42	0.38	119.58	8.17	10.75	20.25	0.31	1.88	9.50	0.45	229.58	7.58
29	chickpeas	0.49	3.21	6.21	10.93	0.28	1.76	4.71	0.40	49.28	8.29	10.46	19.07	0.29	1.82	8.61	0.43	223.40	7.82
30	chickpeas	0.58	3.55	6.25	11.00	0.28	1.76	4.75	0.40	19.00	8.50	9.95	18.65	0.30	1.87	8.70	0.45	297.25	7.90
31	chickpeas	0.43	3.25	6.13	10.78	0.28	1.76	4.65	0.40	40.63	8.43	10.53	19.13	0.29	1.82	8.60	0.43	230.50	7.95
32	chickpeas	0.40	3.50	6.38	10.90	0.26	1.71	4.53	0.38	46.88	8.65	10.55	20.15	0.31	1.91	9.60	0.46	299.50	8.20
33	chickpeas	0.60	3.29	6.46	11.54	0.28	1.79	5.08	0.41	46.66	8.08	10.38	18.83	0.29	1.82	8.46	0.43	205.21	7.58
34	chickpeas	0.77	4.33	7.42	12.00	0.24	1.62	4.58	0.35	63.75	9.00	11.14	19.00	0.26	1.71	7.86	0.38	189.86	8.19
35	chickpeas	0.76	4.55	7.85	12.85	0.24	1.64	5.00	0.35	63.50	9.25	10.90	19.40	0.28	1.78	8.50	0.41	268.25	8.35
36	chickpeas	0.82	4.50	7.75	12.55	0.24	1.62	4.80	0.35	68.75	9.10	11.30	18.90	0.25	1.67	7.60	0.37	171.00	8.85
37	chickpeas	0.68	4.38	7.63	12.63	0.25	1.66	5.00	0.36	58.75	8.63	11.00	19.17	0.27	1.74	8.17	0.40	182.71	8.25
38	chickpeas	0.60	4.25	7.50	12.50	0.25	1.67	5.00	0.37	58.75	9.25	11.42	19.50	0.26	1.71	8.08	0.39	198.33	8.33
39	chickpeas	0.74	4.50	7.71	12.63	0.24	1.64	4.92	0.35	58.96	8.83	11.38	18.92	0.25	1.66	7.54	0.37	135.62	8.50
40	chickpeas	0.62	4.50	7.50	12.00	0.23	1.60	4.50	0.34	60.00	9.13	10.83	18.50	0.26	1.71	7.67	0.39	221.04	8.67
41	chickpeas	0.55	4.50	7.63	12.38	0.24	1.62	4.75	0.35	59.38	9.63	11.00	19.25	0.27	1.75	8.25	0.40	281.88	8.75
42	chickpeas	0.53	4.30	7.75	13.70	0.28	1.77	5.95	0.41	30.25	9.65	12.60	22.40	0.28	1.78	9.80	0.41	209.75	9.55
43	chickpeas	0.68	4.58	7.75	12.75	0.24	1.65	5.00	0.36	50.83	9.75	11.25	18.50	0.24	1.64	7.25	0.36	220.00	8.75
98	chickpeas	0.61	3.83	7.17	11.33	0.23	1.58	4.17	0.33	108.34	8.50	10.67	17.88	0.25	1.68	7.21	0.37	154.58	8.08
99	chickpeas	0.75	4.00	7.25	11.50	0.23	1.59	4.25	0.33	96.25	8.50	10.83	17.50	0.24	1.62	6.67	0.35	111.67	8.13
100	chickpeas	0.83	4.50	7.75	12.25	0.23	1.58	4.50	0.33	83.75	9.50	11.25	18.00	0.23	1.60	6.75	0.34	171.25	9.00

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
101	chickpeas	0.74	4.50	7.63	12.25	0.23	1.61	4.63	0.34	65.63	9.25	10.88	18.00	0.25	1.66	7.13	0.36	201.88	8.75
102	chickpeas	0.55	4.50	7.50	12.10	0.23	1.61	4.60	0.34	55.00	9.10	11.05	18.00	0.24	1.63	6.95	0.35	162.25	8.25
103	chickpeas	0.72	3.94	7.00	11.25	0.23	1.61	4.25	0.34	78.44	8.31	10.13	17.50	0.27	1.73	7.38	0.39	196.56	7.88
104	chickpeas	0.74	4.25	7.50	11.75	0.22	1.57	4.25	0.32	96.25	8.50	10.50	18.25	0.27	1.74	7.75	0.40	197.50	8.25
105	chickpeas	0.57	4.00	7.38	11.75	0.23	1.59	4.38	0.33	101.88	8.88	10.50	18.25	0.27	1.74	7.75	0.40	233.13	8.25
106	chickpeas	0.81	4.50	7.75	12.63	0.24	1.63	4.88	0.35	65.00	9.25	11.38	18.63	0.24	1.64	7.25	0.36	160.63	8.75
185	chickpeas	0.64	5.25	8.38	13.00	0.22	1.55	4.63	0.32	65.63	9.75	10.75	19.13	0.28	1.78	8.38	0.41	323.75	8.00
186	chickpeas	0.70	5.33	8.50	13.33	0.22	1.57	4.83	0.32	59.17	10.25	11.08	19.75	0.28	1.78	8.67	0.41	354.17	8.17
187	chickpeas	0.76	5.17	8.50	13.58	0.23	1.60	5.08	0.34	62.50	9.00	10.50	20.00	0.31	1.90	9.50	0.46	332.50	7.92
188	chickpeas	0.46	5.25	8.50	13.13	0.21	1.54	4.63	0.31	77.50	9.38	11.00	19.75	0.28	1.80	8.75	0.42	283.13	8.00
189	chickpeas	0.54	5.50	8.25	13.00	0.22	1.58	4.75	0.33	23.75	10.00	11.25	19.75	0.27	1.76	8.50	0.40	306.25	8.00
190	chickpeas	0.60	5.17	7.83	13.00	0.25	1.66	5.17	0.36	5.00	9.83	10.50	18.83	0.28	1.79	8.33	0.42	353.33	8.33
191	chickpeas	0.70	5.25	8.50	13.50	0.23	1.59	5.00	0.33	58.75	9.67	11.25	21.08	0.30	1.87	9.83	0.45	341.25	8.00
192	chickpeas	0.48	5.25	8.50	13.25	0.22	1.56	4.75	0.32	71.25	9.25	11.25	19.75	0.27	1.76	8.50	0.40	235.00	7.75
193	chickpeas	0.72	5.25	8.33	13.00	0.22	1.56	4.67	0.32	59.58	9.67	10.83	19.58	0.29	1.81	8.75	0.42	326.67	7.92
194	chickpeas	0.61	5.25	8.08	13.00	0.23	1.61	4.92	0.34	23.33	9.67	10.75	19.33	0.29	1.80	8.58	0.42	326.25	8.50
195	chickpeas	0.51	5.33	8.75	13.25	0.20	1.51	4.50	0.30	99.58	10.00	11.25	19.67	0.27	1.75	8.42	0.40	302.08	8.58
196	chickpeas	0.81	5.25	8.75	13.75	0.22	1.57	5.00	0.33	82.50	9.25	10.63	20.00	0.31	1.88	9.38	0.45	338.13	7.63
197	chickpeas	0.66	5.00	8.25	12.88	0.22	1.56	4.63	0.32	77.50	8.88	10.75	18.75	0.27	1.74	8.00	0.40	221.88	7.50
237	chickpeas	0.46	3.44	6.19	10.81	0.27	1.75	4.63	0.40	30.00	8.50	10.31	19.06	0.30	1.85	8.75	0.44	265.31	8.00
238	chickpeas	0.35	3.08	5.50	9.75	0.28	1.77	4.25	0.40	17.08	8.00	9.25	17.00	0.30	1.84	7.75	0.43	268.75	7.50
239	chickpeas	0.59	2.92	6.50	11.33	0.27	1.74	4.83	0.40	98.75	8.00	10.75	20.00	0.30	1.86	9.25	0.44	201.25	7.50
240	chickpeas	0.40	3.17	6.17	10.92	0.28	1.77	4.75	0.41	47.50	8.17	10.92	19.83	0.29	1.82	8.92	0.43	184.58	7.58
241	chickpeas	0.30	3.00	4.75	8.75	0.30	1.84	4.00	0.43	33.75	8.00	9.25	15.75	0.26	1.70	6.50	0.38	206.25	7.50
242	chickpeas	0.34	3.25	5.50	9.75	0.28	1.77	4.25	0.40	1.25	8.50	9.75	17.50	0.28	1.79	7.75	0.42	268.75	7.75
243	chickpeas	0.41	3.38	6.19	10.38	0.25	1.68	4.19	0.37	57.81	8.75	10.31	17.94	0.27	1.74	7.63	0.40	232.81	7.94
244	chickpeas	0.49	3.13	6.13	10.25	0.25	1.67	4.13	0.37	78.75	8.50	10.75	18.00	0.25	1.67	7.25	0.37	148.75	7.63
245	chickpeas	0.57	3.67	6.25	11.00	0.28	1.76	4.75	0.40	7.92	8.50	10.25	18.75	0.29	1.83	8.50	0.43	258.75	8.08
246	chickpeas	0.47	3.25	6.00	10.00	0.25	1.67	4.00	0.36	61.25	8.00	9.25	17.13	0.30	1.85	7.88	0.44	275.00	7.50
247	chickpeas	0.40	3.50	6.63	11.38	0.26	1.72	4.75	0.39	59.38	9.00	11.38	19.50	0.26	1.71	8.13	0.39	180.63	8.25
248	chickpeas	0.65	4.50	7.63	12.63	0.25	1.66	5.00	0.36	46.88	9.25	11.13	18.75	0.26	1.69	7.63	0.38	203.13	8.50
249	chickpeas	0.71	4.50	7.50	12.00	0.23	1.60	4.50	0.34	60.00	9.25	10.50	19.50	0.30	1.86	9.00	0.44	331.25	9.00
250	chickpeas	0.58	4.50	7.75	12.50	0.23	1.61	4.75	0.34	71.25	8.50	10.50	18.25	0.27	1.74	7.75	0.40	197.50	8.25
251	chickpeas	0.68	4.63	7.75	12.75	0.24	1.65	5.00	0.36	46.88	9.50	11.00	18.25	0.25	1.66	7.25	0.37	220.00	8.81
252	chickpeas	0.71	4.50	7.50	12.13	0.24	1.62	4.63	0.34	53.75	9.50	10.94	18.25	0.25	1.67	7.31	0.37	229.06	9.00
253	chickpeas	0.52	4.42	7.42	11.50	0.22	1.55	4.08	0.32	80.83	9.50	10.17	18.17	0.28	1.79	8.00	0.42	336.67	8.50
254	chickpeas	0.71	4.75	8.00	13.13	0.24	1.64	5.13	0.36	52.50	9.25	10.75	18.63	0.27	1.73	7.88	0.40	251.25	9.00
255	chickpeas	0.71	4.50	7.63	12.75	0.25	1.67	5.13	0.37	40.63	9.25	11.25	19.00	0.26	1.69	7.75	0.38	197.50	8.75
256	chickpeas	0.82	4.56	7.56	12.56	0.25	1.66	5.00	0.36	35.00	9.44	10.88	18.81	0.27	1.73	7.94	0.39	260.31	8.69
257	chickpeas	0.57	4.50	8.00	12.75	0.23	1.59	4.75	0.34	95.00	9.25	11.25	19.25	0.26	1.71	8.00	0.39	210.00	8.50
258	chickpeas	0.61	4.50	8.00	12.75	0.23	1.59	4.75	0.34	95.00	9.63	11.00	20.25	0.30	1.84	9.25	0.44	331.88	8.63
259	chickpeas	0.31	4.00	7.00	11.63	0.25	1.66	4.63	0.36	53.75	7.94	10.13	17.50	0.27	1.73	7.38	0.39	160.94	7.69
260	chickpeas	0.67	4.00	6.94	11.75	0.26	1.69	4.81	0.38	38.44	8.31	9.56	17.50	0.29	1.83	7.94	0.43	278.13	7.75
261	chickpeas	0.60	4.50	7.75	12.75	0.24	1.65	5.00	0.36	58.75	9.50	11.25	19.00	0.26	1.69	7.75	0.38	221.25	9.00
262	chickpeas	0.60	4.33	7.50	12.00	0.23	1.60	4.50	0.34	75.83	9.25	11.00	19.00	0.27	1.73	8.00	0.39	233.75	8.58
263	chickpeas	0.66	4.50	7.50	12.00	0.23	1.60	4.50	0.34	60.00	9.25	10.50	18.50	0.28	1.76	8.00	0.41	281.25	8.25
264	chickpeas	0.75	4.50	7.58	12.00	0.23	1.58	4.42	0.33	72.08	9.25	10.50	19.17	0.29	1.83	8.67	0.43	314.58	8.25
265	chickpeas	0.73	4.25	7.50	12.50	0.25	1.67	5.00	0.37	58.75	9.25	10.50	18.75	0.28	1.79	8.25	0.42	293.75	8.25

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
266	chickpeas	0.63	4.50	7.75	13.25	0.26	1.71	5.50	0.38	33.75	9.25	11.75	19.00	0.24	1.62	7.25	0.35	125.00	8.25
267	chickpeas	0.66	5.25	8.00	13.00	0.24	1.63	5.00	0.35	11.25	9.50	11.25	18.25	0.24	1.62	7.00	0.35	183.75	9.00
268	chickpeas	0.71	4.75	7.50	12.00	0.23	1.60	4.50	0.34	36.25	9.25	11.00	17.50	0.23	1.59	6.50	0.34	158.75	8.25
269	chickpeas	0.76	4.50	7.75	12.75	0.24	1.65	5.00	0.36	58.75	9.25	11.00	19.25	0.27	1.75	8.25	0.40	246.25	8.25
270	chickpeas	0.58	4.00	7.25	11.25	0.22	1.55	4.00	0.32	108.75	8.50	10.50	17.50	0.25	1.67	7.00	0.37	160.00	7.75
360	chickpeas	0.79	4.00	7.25	11.50	0.23	1.59	4.25	0.33	96.25	9.00	11.00	17.63	0.23	1.60	6.63	0.34	141.25	8.25
361	chickpeas	0.78	4.13	7.25	11.50	0.23	1.59	4.25	0.33	84.38	8.50	11.00	17.00	0.21	1.55	6.00	0.32	62.50	8.50
362	chickpeas	0.63	3.92	7.08	11.33	0.23	1.60	4.25	0.34	88.33	8.75	10.17	17.75	0.27	1.75	7.58	0.40	244.58	8.58
363	chickpeas	0.65	4.00	7.38	11.63	0.22	1.58	4.25	0.33	108.13	8.50	10.50	17.50	0.25	1.67	7.00	0.37	160.00	8.25
364	chickpeas	0.75	4.38	7.50	12.25	0.24	1.63	4.75	0.35	59.38	8.50	10.88	18.63	0.26	1.71	7.75	0.39	161.88	8.00
365	chickpeas	0.85	4.58	7.75	12.50	0.23	1.61	4.75	0.34	63.33	9.50	11.58	18.00	0.22	1.55	6.42	0.32	122.92	9.00
366	chickpeas	0.83	4.63	7.63	12.75	0.25	1.67	5.13	0.37	28.75	9.00	10.75	18.38	0.26	1.71	7.63	0.39	215.00	9.00
367	chickpeas	0.77	4.50	7.50	12.13	0.24	1.62	4.63	0.34	53.75	8.88	11.00	18.88	0.26	1.72	7.88	0.39	191.88	8.50
368	chickpeas	0.54	4.50	7.56	11.63	0.21	1.54	4.06	0.31	87.81	9.50	11.13	18.19	0.24	1.63	7.06	0.36	198.75	8.88
369	chickpeas	0.77	4.38	7.63	12.44	0.24	1.63	4.81	0.35	68.13	9.25	11.50	18.75	0.24	1.63	7.25	0.35	148.75	8.81
370	chickpeas	0.58	4.17	7.33	12.17	0.25	1.66	4.83	0.36	59.16	9.25	10.67	18.00	0.26	1.69	7.33	0.38	232.08	8.25
371	chickpeas	0.69	4.50	7.75	12.75	0.24	1.65	5.00	0.36	58.75	9.50	11.25	18.25	0.24	1.62	7.00	0.35	183.75	9.00
372	chickpeas	0.79	4.33	7.42	12.00	0.24	1.62	4.58	0.35	63.75	8.50	10.83	18.58	0.26	1.72	7.75	0.39	165.83	8.58
373	chickpeas	0.54	5.08	8.75	15.42	0.28	1.76	6.67	0.41	15.00	10.50	12.67	22.33	0.28	1.76	9.67	0.41	277.50	9.58
374	chickpeas	0.75	4.63	7.81	12.75	0.24	1.63	4.94	0.35	55.94	9.25	11.13	19.31	0.27	1.74	8.19	0.40	231.25	8.81
375	chickpeas	0.75	4.50	7.50	12.25	0.24	1.63	4.75	0.35	47.50	8.50	11.25	17.75	0.22	1.58	6.50	0.33	63.75	8.25
376	chickpeas	0.66	4.00	7.50	12.25	0.24	1.63	4.75	0.35	95.00	8.50	10.75	17.17	0.23	1.60	6.42	0.34	107.08	8.50
377	chickpeas	0.77	4.40	7.50	12.00	0.23	1.60	4.50	0.34	69.50	9.10	11.00	18.25	0.25	1.66	7.25	0.37	182.00	8.55
378	chickpeas	0.59	4.50	7.75	13.25	0.26	1.71	5.50	0.38	33.75	9.50	11.50	20.88	0.29	1.82	9.38	0.43	278.75	8.50
379	chickpeas	0.80	4.50	7.96	13.08	0.24	1.64	5.13	0.36	72.29	9.25	11.50	19.13	0.25	1.66	7.63	0.37	167.50	8.88
380	chickpeas	0.63	3.19	5.88	11.94	0.34	2.03	6.06	0.50	47.81	8.31	9.94	19.13	0.32	1.92	9.19	0.47	305.00	7.88
381	chickpeas	0.75	4.50	7.75	12.75	0.24	1.65	5.00	0.36	58.75	9.00	11.75	18.50	0.22	1.57	6.75	0.33	76.25	9.00
382	chickpeas	0.60	5.75	10.00	17.00	0.26	1.70	7.00	0.38	53.75	10.50	13.00	23.00	0.28	1.77	10.00	0.41	262.50	10.50
491	chickpeas		3.25	6.42	11.42	0.28	1.78	5.00	0.41	50.83	8.00	10.75	19.00	0.28	1.77	8.25	0.41	151.25	7.33
492	chickpeas		4.25	7.25	11.75	0.24	1.62	4.50	0.35	60.00	8.50	11.00	18.25	0.25	1.66	7.25	0.37	125.00	8.25
494	chickpeas	0.76	4.38	7.50	12.25	0.24	1.63	4.75	0.35	59.38	8.50	11.13	18.00	0.24	1.62	6.88	0.35	94.38	8.25
495	chickpeas	0.83	4.43	7.57	12.32	0.24	1.63	4.75	0.35	61.07	8.43	11.46	18.04	0.22	1.57	6.57	0.33	40.18	8.64
496	chickpeas	0.62	4.00	7.25	11.75	0.24	1.62	4.50	0.35	83.75	8.50	10.75	18.00	0.25	1.67	7.25	0.37	148.75	7.75
497	chickpeas	0.70	4.00	7.00	11.25	0.23	1.61	4.25	0.34	72.50	7.75	9.75	17.50	0.28	1.79	7.75	0.42	197.50	7.75
548	chickpeas	0.79	5.13	8.50	13.25	0.22	1.56	4.75	0.32	83.13	8.50	10.88	20.00	0.30	1.84	9.13	0.44	230.63	7.50
549	chickpeas	0.70	5.25	8.25	13.25	0.23	1.61	5.00	0.34	35.00	10.00	11.25	19.75	0.27	1.76	8.50	0.40	306.25	8.75
550	chickpeas	0.63	5.25	8.75	13.50	0.21	1.54	4.75	0.31	95.00	10.25	11.50	19.50	0.26	1.70	8.00	0.38	281.25	7.88
551	chickpeas	0.49	5.50	8.50	13.13	0.21	1.54	4.63	0.31	53.75	10.00	11.25	19.75	0.27	1.76	8.50	0.40	306.25	8.50
552	chickpeas	0.49	5.25	8.25	12.75	0.21	1.55	4.50	0.31	60.00	9.50	11.25	18.75	0.25	1.67	7.50	0.37	208.75	8.00
553	chickpeas	0.62	5.25	8.50	13.50	0.23	1.59	5.00	0.33	58.75	10.00	11.25	21.75	0.32	1.93	10.50	0.47	406.25	8.50
554	chickpeas	0.47	5.25	8.50	13.25	0.22	1.56	4.75	0.32	71.25	10.00	11.25	19.75	0.27	1.76	8.50	0.40	306.25	8.00
555	chickpeas	0.65	5.13	7.88	12.38	0.22	1.57	4.50	0.33	36.25	9.50	10.75	18.50	0.26	1.72	7.75	0.39	268.75	8.00
556	chickpeas	0.86	5.33	9.17	13.83	0.20	1.51	4.67	0.30	130.84	9.25	10.92	20.00	0.29	1.83	9.08	0.43	295.83	7.67
557	chickpeas	0.79	5.00	8.25	13.00	0.22	1.58	4.75	0.33	71.25	8.50	10.50	20.00	0.31	1.90	9.50	0.46	285.00	7.00
558	chickpeas	0.48	5.25	8.75	13.50	0.21	1.54	4.75	0.31	95.00	10.00	11.25	19.75	0.27	1.76	8.50	0.40	306.25	7.75
559	chickpeas	0.69	5.33	8.33	13.00	0.22	1.56	4.67	0.32	51.67	10.00	11.25	20.00	0.28	1.78	8.75	0.41	318.75	8.33
560	chickpeas	0.55	5.25	9.00	13.75	0.21	1.53	4.75	0.31	118.75	10.00	11.25	21.50	0.31	1.91	10.25	0.46	393.75	8.00
561	chickpeas	0.64	5.25	8.50	13.38	0.22	1.57	4.88	0.33	65.00	9.50	11.25	21.50	0.31	1.91	10.25	0.46	346.25	8.38

Appendix I: Yield Map and Satellite Parameter Database

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
562	chickpeas	0.47	5.21	8.33	13.00	0.22	1.56	4.67	0.32	63.54	9.67	10.88	19.33	0.28	1.78	8.46	0.41	308.13	8.00
563	chickpeas	0.62	5.33	8.58	13.75	0.23	1.60	5.17	0.34	50.42	10.00	11.50	21.42	0.30	1.86	9.92	0.45	353.33	8.42
564	chickpeas	0.69	5.00	8.25	14.00	0.26	1.70	5.75	0.38	21.25	9.83	11.50	22.33	0.32	1.94	10.83	0.47	383.33	7.92
565	chickpeas	0.52	5.00	7.92	12.58	0.23	1.59	4.67	0.33	43.75	9.75	10.75	19.33	0.29	1.80	8.58	0.42	334.17	7.92
566	chickpeas	0.66	5.25	8.50	13.00	0.21	1.53	4.50	0.31	83.75	9.50	10.75	19.75	0.30	1.84	9.00	0.44	331.25	8.00
567	chickpeas	0.67	5.50	8.58	13.42	0.22	1.56	4.83	0.32	51.25	9.83	11.25	19.75	0.27	1.76	8.50	0.40	290.42	8.17
568	chickpeas	0.51	5.50	8.85	13.50	0.21	1.53	4.65	0.31	85.75	10.00	11.15	19.50	0.27	1.75	8.35	0.40	308.25	8.40
575	chickpeas	0.35	3.00	6.25	11.75	0.31	1.88	5.50	0.45	33.75	8.38	10.75	19.00	0.28	1.77	8.25	0.41	186.88	7.50
15	lentil	0.41	4.83	7.73	12.45	0.23	1.61	4.72	0.34	40.16	8.19	9.81	17.73	0.29	1.81	7.92	0.42	241.72	7.80
16	lentil	0.78	4.70	7.59	12.23	0.23	1.61	4.64	0.34	42.38	8.32	9.75	17.59	0.29	1.80	7.84	0.42	256.02	7.68
17	lentil	1.22	4.55	7.60	12.90	0.26	1.70	5.30	0.38	24.75	8.00	9.30	19.55	0.36	2.10	10.25	0.52	389.00	7.35
18	lentil	0.72	4.81	7.69	12.50	0.24	1.63	4.81	0.35	32.50	8.00	10.00	17.88	0.28	1.79	7.88	0.42	203.75	7.75
19	lentil	0.89	4.50	7.33	11.83	0.23	1.61	4.50	0.34	44.17	8.00	9.58	17.50	0.29	1.83	7.92	0.43	245.42	7.75
226	lentil	0.62	4.50	7.25	11.75	0.24	1.62	4.50	0.35	36.25	7.75	9.50	16.75	0.28	1.76	7.25	0.41	196.25	7.50
227	lentil	0.82	4.50	7.50	11.92	0.23	1.59	4.42	0.33	64.17	8.00	9.58	18.33	0.31	1.91	8.75	0.46	287.08	7.50
228	lentil	0.79	4.50	7.38	11.88	0.23	1.61	4.50	0.34	48.13	8.00	9.75	17.50	0.28	1.79	7.75	0.42	221.25	7.50
229	lentil	0.20	3.88	6.88	12.50	0.29	1.82	5.63	0.42	3.75	8.25	9.75	18.25	0.30	1.87	8.50	0.45	282.50	7.63
230	lentil	0.57	4.88	7.75	12.88	0.25	1.66	5.13	0.36	16.88	8.25	9.75	18.25	0.30	1.87	8.50	0.45	282.50	7.75
231	lentil	0.43	4.75	7.75	13.00	0.25	1.68	5.25	0.37	22.50	8.50	10.50	18.25	0.27	1.74	7.75	0.40	197.50	7.75
232	lentil	0.66	4.69	7.56	12.38	0.24	1.64	4.81	0.35	32.50	8.75	9.75	18.00	0.30	1.85	8.25	0.44	317.50	7.88
233	lentil	0.59	4.50	7.42	11.75	0.23	1.58	4.33	0.33	60.42	7.83	10.08	17.83	0.28	1.77	7.75	0.41	173.75	7.67
234	lentil	0.74	4.63	7.50	12.00	0.23	1.60	4.50	0.34	48.13	8.00	9.75	17.50	0.28	1.79	7.75	0.42	221.25	7.75
235	lentil	0.63	4.75	7.75	12.75	0.24	1.65	5.00	0.36	35.00	8.00	9.75	18.25	0.30	1.87	8.50	0.45	258.75	7.50
236	lentil	0.15	4.88	7.88	13.13	0.25	1.67	5.25	0.37	22.50	8.50	10.13	19.00	0.30	1.88	8.88	0.45	289.38	7.75
572	lentil		4.88	7.88	12.50	0.23	1.59	4.63	0.33	53.75	8.50	10.50	17.13	0.24	1.63	6.63	0.35	141.25	8.38
573	lentil		4.58	7.50	11.67	0.22	1.56	4.17	0.32	68.75	8.33	10.25	15.75	0.21	1.54	5.50	0.31	92.92	8.33
574	lentil		4.63	7.88	12.88	0.24	1.63	5.00	0.35	58.75	8.00	9.88	17.50	0.28	1.77	7.63	0.41	203.13	8.00
1	wheat	0.77	5.45	8.20	18.10	0.38	2.21	9.90	0.55	233.75	6.85	6.40	33.20	0.68	5.19	26.80	1.00	1382.75	4.35
2	wheat	0.86	5.04	7.29	16.71	0.39	2.29	9.42	0.58	257.08	6.42	6.25	29.83	0.65	4.77	23.58	0.97	1195.00	4.13
3	wheat	0.49	5.75	8.63	17.63	0.34	2.04	9.00	0.50	176.88	7.50	7.13	30.19	0.62	4.24	23.06	0.91	1188.75	4.75
4	wheat	0.71	5.50	8.25	17.50	0.36	2.12	9.25	0.53	201.25	6.00	6.75	30.25	0.64	4.48	23.50	0.94	1103.75	4.00
5	wheat	0.56	5.67	8.33	17.83	0.36	2.14	9.50	0.53	221.67	8.00	6.75	29.58	0.63	4.38	22.83	0.93	1260.41	5.42
6	wheat	0.78	5.17	7.67	16.83	0.37	2.20	9.17	0.55	220.83	7.33	6.75	29.67	0.63	4.40	22.92	0.93	1201.25	4.33
7	wheat	0.80	5.08	7.75	17.33	0.38	2.24	9.58	0.56	225.83	7.00	5.83	31.42	0.69	5.39	25.58	1.02	1390.01	4.00
8	wheat	0.98	4.92	8.17	17.08	0.35	2.09	8.92	0.52	137.08	6.00	4.75	29.67	0.72	6.25	24.92	1.07	1364.59	3.42
9	wheat	0.98	5.06	7.69	17.63	0.39	2.29	9.94	0.58	247.50	5.88	5.50	33.44	0.72	6.08	27.94	1.06	1432.50	3.88
10	wheat	1.06	5.13	7.75	17.81	0.39	2.30	10.06	0.58	253.75	5.88	4.75	33.69	0.75	7.09	28.94	1.11	1553.75	3.81
11	wheat	0.59	4.25	7.38	16.63	0.39	2.25	9.25	0.57	165.63	5.25	5.13	30.00	0.71	5.85	24.88	1.05	1255.63	3.75
12	wheat	0.83	5.06	7.94	17.56	0.38	2.21	9.63	0.56	208.13	6.81	5.00	34.19	0.74	6.84	29.19	1.10	1631.56	4.25
13	wheat	1.02	5.00	7.68	17.79	0.40	2.32	10.11	0.58	250.89	6.04	4.96	33.89	0.74	6.83	28.93	1.10	1548.21	4.14
14	wheat	0.88	4.88	7.38	17.63	0.41	2.39	10.25	0.60	275.00	6.25	5.00	33.75	0.74	6.75	28.75	1.10	1556.25	4.25
44	wheat	0.66	4.25	6.85	14.30	0.35	2.09	7.45	0.52	125.50	5.85	5.50	25.85	0.65	4.70	20.35	0.96	1050.75	4.45
45	wheat	0.73	3.68	5.96	13.79	0.40	2.31	7.82	0.58	173.93	5.64	4.96	32.54	0.74	6.55	27.57	1.09	1443.04	4.32
46	wheat	1.30	4.07	6.79	14.18	0.35	2.09	7.39	0.52	111.78	5.75	5.61	28.32	0.67	5.05	22.71	0.99	1149.29	4.04
47	wheat	0.88	3.95	6.95	14.05	0.34	2.02	7.10	0.50	70.00	5.65	5.60	27.75	0.66	4.96	22.15	0.98	1112.25	4.00
48	wheat	0.85	4.00	7.42	15.17	0.34	2.04	7.75	0.50	62.92	5.75	6.75	27.08	0.60	4.01	20.33	0.89	921.66	4.00
49	wheat	0.10	4.29	7.13	14.88	0.35	2.09	7.75	0.52	118.33	6.17	5.92	28.71	0.66	4.85	22.79	0.97	1163.33	4.42
50	wheat	0.10	4.25	6.81	14.75	0.37	2.17	7.94	0.54	153.44	5.75	5.00	30.38	0.72	6.08	25.38	1.06	1340.00	4.00

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
51	wheat	0.46	4.50	7.08	15.92	0.38	2.25	8.83	0.56	196.25	5.33	5.25	29.17	0.69	5.56	23.92	1.03	1203.75	3.75
52	wheat	0.63	4.25	7.13	15.38	0.37	2.16	8.25	0.54	139.38	6.00	5.50	29.63	0.69	5.39	24.13	1.02	1253.75	4.00
53	wheat	0.05	4.50	7.25	14.75	0.34	2.03	7.50	0.50	113.75	6.25	6.50	27.13	0.61	4.17	20.63	0.91	1007.50	4.75
54	wheat	0.04	4.38	7.13	15.00	0.36	2.11	7.88	0.52	132.50	6.00	6.13	26.88	0.63	4.39	20.75	0.93	1025.63	4.75
55	wheat	0.06	4.17	6.67	16.17	0.42	2.42	9.50	0.61	237.50	5.50	5.00	31.00	0.72	6.20	26.00	1.07	1347.50	3.75
56	wheat	0.61	3.83	6.33	15.33	0.42	2.42	9.00	0.61	212.50	5.50	5.92	29.92	0.67	5.06	24.00	0.99	1160.42	4.50
57	wheat	0.31	4.31	7.06	14.94	0.36	2.12	7.88	0.53	132.50	6.00	6.06	29.06	0.65	4.79	23.00	0.97	1144.06	4.38
58	wheat	0.30	4.33	7.17	14.92	0.35	2.08	7.75	0.51	118.33	5.75	6.00	28.50	0.65	4.75	22.50	0.96	1101.25	4.42
59	wheat	0.76	3.94	6.69	13.44	0.34	2.01	6.75	0.49	76.25	5.75	5.69	28.00	0.66	4.92	22.31	0.98	1121.56	4.06
60	wheat	0.29	4.25	7.00	16.00	0.39	2.29	9.00	0.57	188.75	5.50	5.13	30.50	0.71	5.95	25.38	1.05	1304.38	4.00
61	wheat	0.31	4.08	6.75	15.25	0.39	2.26	8.50	0.57	171.67	5.50	5.00	30.25	0.72	6.05	25.25	1.06	1310.00	3.92
72	wheat	0.06	3.85	5.00	20.65	0.61	4.13	15.65	0.90	673.25	5.70	3.40	40.45	0.84	11.90	37.05	1.25	2071.00	3.80
73	wheat	0.11	4.06	5.56	19.38	0.55	3.48	13.81	0.81	548.13	6.19	3.75	36.25	0.81	9.67	32.50	1.20	1856.56	3.94
74	wheat	0.01	4.25	6.00	18.25	0.51	3.04	12.25	0.74	446.25	6.00	4.25	35.58	0.79	8.37	31.33	1.17	1732.91	4.42
75	wheat	0.11	4.00	5.75	18.50	0.53	3.22	12.75	0.77	471.25	5.42	4.50	29.75	0.74	6.61	25.25	1.09	1349.58	4.08
76	wheat	0.07	4.50	7.50	21.25	0.48	2.83	13.75	0.71	402.50	6.25	5.50	30.25	0.69	5.50	24.75	1.02	1308.75	4.25
77	wheat	0.08	3.75	5.00	17.38	0.55	3.48	12.38	0.81	500.00	4.75	3.75	37.75	0.82	10.07	34.00	1.21	1795.00	3.75
78	wheat	0.17	3.75	5.25	16.38	0.51	3.12	11.13	0.75	413.75	5.75	4.25	30.00	0.75	7.06	25.75	1.11	1430.00	4.00
79	wheat	0.94	3.80	5.95	16.35	0.47	2.75	10.40	0.68	315.75	5.45	4.25	28.65	0.74	6.74	24.40	1.10	1334.00	4.00
80	wheat	0.88	3.81	5.94	16.31	0.47	2.75	10.38	0.68	316.88	5.50	4.25	27.69	0.73	6.51	23.44	1.08	1290.63	4.00
81	wheat	0.93	3.75	5.75	17.13	0.50	2.98	11.38	0.73	378.75	4.50	4.00	31.00	0.77	7.75	27.00	1.14	1397.50	3.25
82	wheat	1.03	4.00	5.50	19.25	0.56	3.50	13.75	0.82	545.00	4.50	4.00	34.75	0.79	8.69	30.75	1.18	1585.00	3.25
83	wheat	1.16	3.33	4.75	19.17	0.60	4.04	14.42	0.89	586.25	4.50	3.75	33.25	0.80	8.87	29.50	1.18	1546.25	3.58
84	wheat	1.27	3.63	4.75	18.75	0.60	3.95	14.00	0.88	593.13	4.50	3.75	33.38	0.80	8.90	29.63	1.18	1552.50	3.25
85	wheat	1.07	4.00	6.17	17.21	0.47	2.79	11.04	0.69	346.25	5.50	4.67	29.08	0.72	6.23	24.42	1.07	1299.99	3.75
86	wheat	0.39	4.25	6.00	17.83	0.50	2.97	11.83	0.73	425.42	5.25	4.08	32.25	0.78	7.90	28.17	1.15	1519.17	3.75
87	wheat	0.44	3.88	5.38	18.88	0.56	3.51	13.50	0.82	532.50	5.25	4.25	32.38	0.77	7.62	28.13	1.14	1501.25	3.63
88	wheat	0.94	3.33	5.00	19.33	0.59	3.87	14.33	0.87	558.33	4.92	4.00	32.50	0.78	8.13	28.50	1.16	1512.08	3.00
89	wheat	0.88	3.63	5.13	19.00	0.58	3.71	13.88	0.85	551.25	4.75	3.75	29.50	0.77	7.87	25.75	1.14	1382.50	3.25
90	wheat	0.41	3.75	5.75	19.25	0.54	3.35	13.50	0.79	485.00	5.25	3.50	31.00	0.80	8.86	27.50	1.18	1541.25	4.00
91	wheat	1.13	5.31	8.38	18.25	0.37	2.18	9.88	0.55	202.81	5.75	4.75	32.19	0.74	6.78	27.44	1.10	1466.88	3.75
92	wheat	1.30	5.92	8.58	18.83	0.37	2.19	10.25	0.55	259.17	6.50	6.00	33.75	0.70	5.63	27.75	1.03	1435.00	4.58
93	wheat	0.88	5.00	8.50	19.00	0.38	2.24	10.50	0.56	192.50	6.25	4.75	33.50	0.75	7.05	28.75	1.11	1580.00	3.75
94	wheat	1.20	5.00	7.75	17.25	0.38	2.23	9.50	0.56	213.75	5.50	3.25	31.75	0.81	9.77	28.50	1.20	1638.75	3.75
95	wheat	1.22	5.00	7.75	18.00	0.40	2.32	10.25	0.59	251.25	6.00	4.75	34.25	0.76	7.21	29.50	1.12	1593.75	4.25
96	wheat	0.47	5.88	8.63	18.50	0.36	2.14	9.88	0.54	232.50	6.50	5.75	33.75	0.71	5.87	28.00	1.05	1471.25	4.00
97	wheat	0.49	5.50	8.75	19.25	0.38	2.20	10.50	0.55	216.25	7.00	6.75	30.75	0.64	4.56	24.00	0.95	1223.75	4.25
117	wheat	1.19	5.50	8.25	19.88	0.41	2.41	11.63	0.61	320.00	6.00	5.38	34.50	0.73	6.42	29.13	1.08	1515.63	3.88
118	wheat	1.41	6.00	8.50	19.00	0.38	2.24	10.50	0.56	287.50	7.50	6.00	33.00	0.69	5.50	27.00	1.03	1492.50	4.00
119	wheat	0.79	5.13	8.13	18.75	0.40	2.31	10.63	0.58	246.25	5.75	4.75	34.00	0.75	7.16	29.25	1.12	1557.50	3.75
121	wheat	1.23	5.50	8.50	19.50	0.39	2.29	11.00	0.58	265.00	7.00	4.75	34.00	0.75	7.16	29.25	1.12	1676.25	4.00
122	wheat	0.95	6.00	8.50	20.75	0.42	2.44	12.25	0.62	375.00	6.38	4.88	35.00	0.76	7.18	30.13	1.12	1648.75	4.00
123	wheat	1.04	5.25	8.25	19.25	0.40	2.33	11.00	0.59	265.00	6.00	4.75	34.00	0.75	7.16	29.25	1.12	1581.25	4.00
124	wheat	1.13	6.00	8.75	20.25	0.40	2.31	11.50	0.58	313.75	7.00	6.25	34.00	0.69	5.44	27.75	1.02	1458.75	4.00
125	wheat	1.09	3.88	6.50	12.63	0.32	1.94	6.13	0.47	56.88	7.00	6.75	23.13	0.55	3.43	16.38	0.81	842.50	5.75
126	wheat	0.54	4.00	6.50	13.42	0.35	2.06	6.92	0.51	108.33	7.00	7.00	24.92	0.56	3.56	17.92	0.83	895.83	6.00
127	wheat	0.34	3.88	6.50	13.13	0.34	2.02	6.63	0.49	81.88	7.00	7.00	24.75	0.56	3.54	17.75	0.83	887.50	6.00
128	wheat	1.14	4.00	6.42	12.58	0.32	1.96	6.17	0.47	78.75	6.75	7.33	22.50	0.51	3.07	15.17	0.75	702.92	5.75

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
129	wheat	1.27	4.00	6.63	13.13	0.33	1.98	6.50	0.48	75.63	6.63	7.25	22.25	0.51	3.07	15.00	0.75	690.63	6.00
130	wheat	1.19	4.00	6.75	13.25	0.33	1.96	6.50	0.48	63.75	7.00	7.00	24.00	0.55	3.43	17.00	0.81	850.00	5.56
131	wheat	0.97	3.92	6.50	13.42	0.35	2.06	6.92	0.51	100.42	7.00	7.00	24.83	0.56	3.55	17.83	0.83	891.67	5.83
132	wheat	0.53	4.00	6.50	12.50	0.32	1.92	6.00	0.46	62.50	7.00	8.00	22.00	0.47	2.75	14.00	0.69	605.00	6.00
133	wheat	0.01	3.90	6.45	12.90	0.33	2.00	6.45	0.49	80.25	7.30	7.40	23.15	0.52	3.13	15.75	0.76	778.00	5.85
134	wheat	0.11	4.13	6.75	13.63	0.34	2.02	6.88	0.49	94.38	6.81	6.88	25.50	0.58	3.71	18.63	0.85	925.31	5.69
135	wheat	0.65	4.08	6.50	13.42	0.35	2.06	6.92	0.51	116.25	6.67	6.50	25.50	0.59	3.92	19.00	0.88	965.83	5.67
136	wheat	0.02	4.00	6.67	12.92	0.32	1.94	6.25	0.47	59.17	7.50	8.00	22.75	0.48	2.84	14.75	0.71	690.00	5.75
137	wheat	0.22	3.75	6.25	12.88	0.35	2.06	6.63	0.51	93.75	6.00	6.88	24.50	0.56	3.56	17.63	0.83	798.13	5.75
138	wheat	0.26	4.13	6.63	13.50	0.34	2.04	6.88	0.50	106.25	7.00	7.00	23.75	0.54	3.39	16.75	0.80	837.50	5.50
139	wheat	1.37	4.50	7.50	14.63	0.32	1.95	7.13	0.47	71.25	7.00	7.00	26.50	0.58	3.79	19.50	0.86	975.00	5.75
140	wheat	0.93	3.83	6.25	12.33	0.33	1.97	6.08	0.48	74.58	6.75	7.08	22.83	0.53	3.22	15.75	0.78	755.83	5.50
141	wheat	0.52	4.00	6.55	13.45	0.35	2.05	6.90	0.50	102.75	7.00	6.90	24.95	0.57	3.62	18.05	0.84	912.00	5.70
142	wheat	1.03	3.75	6.42	12.17	0.31	1.90	5.75	0.45	34.17	6.50	6.75	22.08	0.53	3.27	15.33	0.78	742.92	5.58
143	wheat	0.01	3.88	6.50	12.25	0.31	1.88	5.75	0.45	38.13	6.50	7.63	23.00	0.50	3.02	15.38	0.74	661.88	5.75
160	wheat	0.71	4.50	7.00	17.00	0.42	2.43	10.00	0.61	262.50	4.75	4.75	30.00	0.73	6.32	25.25	1.07	1262.50	3.75
161	wheat	1.12	5.00	7.50	19.75	0.45	2.63	12.25	0.66	375.00	6.00	4.75	34.75	0.76	7.32	30.00	1.13	1618.75	3.75
162	wheat	1.13	5.13	7.63	19.00	0.43	2.49	11.38	0.63	331.25	6.00	5.25	35.13	0.74	6.69	29.88	1.10	1565.00	3.75
163	wheat	1.16	5.50	7.92	19.42	0.42	2.45	11.50	0.62	345.42	6.33	5.25	34.25	0.73	6.52	29.00	1.09	1552.92	3.75
164	wheat	1.40	4.75	7.00	18.75	0.46	2.68	11.75	0.67	373.75	7.00	4.75	34.25	0.76	7.21	29.50	1.12	1688.75	4.00
165	wheat	0.83	4.50	7.00	16.75	0.41	2.39	9.75	0.60	250.00	5.00	4.75	30.63	0.73	6.45	25.88	1.08	1317.50	3.75
166	wheat	0.92	5.00	7.38	18.38	0.43	2.49	11.00	0.63	324.38	5.75	5.25	33.00	0.73	6.29	27.75	1.07	1435.00	3.75
167	wheat	1.03	5.00	7.40	19.70	0.45	2.66	12.30	0.67	387.00	5.80	5.15	34.30	0.74	6.66	29.15	1.09	1519.25	3.80
168	wheat	1.29	4.88	7.38	18.13	0.42	2.46	10.75	0.62	300.00	5.75	4.75	34.38	0.76	7.24	29.63	1.12	1576.25	3.50
169	wheat	1.27	4.50	7.00	17.88	0.44	2.55	10.88	0.64	306.25	5.50	4.38	33.50	0.77	7.66	29.13	1.14	1563.13	3.25
198	wheat	0.67	6.00	8.75	18.25	0.35	2.09	9.50	0.52	213.75	8.25	6.75	29.50	0.63	4.37	22.75	0.93	1280.00	5.25
200	wheat	0.85	5.50	8.00	17.00	0.36	2.13	9.00	0.53	212.50	7.50	6.75	28.25	0.61	4.19	21.50	0.91	1146.25	5.25
201	wheat	0.99	4.50	7.88	16.00	0.34	2.03	8.13	0.50	85.63	5.75	5.50	28.25	0.67	5.14	22.75	1.00	1161.25	4.00
202	wheat	0.81	5.75	8.25	17.13	0.35	2.08	8.88	0.51	206.25	7.88	7.25	29.13	0.60	4.02	21.88	0.89	1153.13	5.25
203	wheat	0.57	5.75	8.75	17.75	0.34	2.03	9.00	0.50	165.00	7.50	6.75	30.75	0.64	4.56	24.00	0.95	1271.25	4.75
205	wheat	0.87	5.75	8.75	17.75	0.34	2.03	9.00	0.50	165.00	8.25	6.75	31.00	0.64	4.59	24.25	0.95	1355.00	5.25
206	wheat	1.10	5.25	7.88	17.63	0.38	2.24	9.75	0.56	238.13	6.00	5.50	31.75	0.70	5.77	26.25	1.04	1360.00	4.13
207	wheat	0.79	5.25	7.75	16.75	0.37	2.16	9.00	0.54	212.50	7.00	6.25	29.50	0.65	4.72	23.25	0.96	1233.75	4.75
208	wheat	0.78	5.00	8.00	17.25	0.37	2.16	9.25	0.54	177.50	7.00	6.25	31.75	0.67	5.08	25.50	0.99	1346.25	4.25
209	wheat	0.91	5.25	8.25	18.88	0.39	2.29	10.63	0.58	246.25	6.00	5.25	34.75	0.74	6.62	29.50	1.09	1546.25	4.00
210	wheat	1.08	5.00	7.63	16.88	0.38	2.21	9.25	0.56	213.13	6.25	5.13	31.00	0.72	6.05	25.88	1.06	1400.63	4.00
211	wheat	0.86	5.25	8.00	17.75	0.38	2.22	9.75	0.56	226.25	7.00	5.50	32.88	0.71	5.98	27.38	1.06	1511.25	4.25
212	wheat	0.89	5.25	7.63	17.88	0.40	2.34	10.25	0.59	286.88	6.25	4.75	33.75	0.75	7.11	29.00	1.12	1592.50	4.25
213	wheat	0.69	4.42	7.50	16.83	0.38	2.24	9.33	0.56	173.75	5.50	5.00	28.75	0.70	5.75	23.75	1.04	1235.00	4.08
214	wheat	0.96	5.13	7.63	17.88	0.40	2.34	10.25	0.59	275.00	6.63	5.13	33.75	0.74	6.59	28.63	1.09	1573.75	4.50
215	wheat	1.09	5.19	7.81	17.94	0.39	2.30	10.13	0.58	256.88	6.25	4.88	33.50	0.75	6.87	28.63	1.10	1561.88	4.25
216	wheat	0.93	5.00	7.50	19.25	0.44	2.57	11.75	0.65	350.00	6.25	4.75	35.50	0.76	7.47	30.75	1.13	1680.00	4.25
217	wheat	0.68	5.25	7.88	17.38	0.38	2.21	9.50	0.55	225.63	6.00	6.25	33.25	0.68	5.32	27.00	1.01	1326.25	4.75
218	wheat	0.80	5.00	7.67	17.67	0.39	2.30	10.00	0.58	246.67	5.67	4.75	33.25	0.75	7.00	28.50	1.11	1512.08	3.83
219	wheat	0.90	5.17	8.17	17.33	0.36	2.12	9.17	0.53	173.33	6.50	5.58	31.75	0.70	5.69	26.17	1.04	1395.42	4.25
220	wheat	0.90	5.25	8.50	17.75	0.35	2.09	9.25	0.52	153.75	7.00	6.25	30.75	0.66	4.92	24.50	0.98	1296.25	4.00
271	wheat	0.32	4.50	7.38	15.13	0.34	2.05	7.75	0.51	114.38	6.25	6.75	27.13	0.60	4.02	20.38	0.89	971.25	4.25
272	wheat	0.88	4.50	7.25	15.25	0.36	2.10	8.00	0.52	138.75	5.75	5.50	29.83	0.69	5.42	24.33	1.02	1240.41	4.25

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
273	wheat	1.10	4.25	7.17	13.67	0.31	1.91	6.50	0.46	47.92	6.25	6.25	27.75	0.63	4.44	21.50	0.93	1075.00	4.08
274	wheat	1.20	4.17	6.92	14.08	0.34	2.04	7.17	0.50	97.08	5.75	5.33	27.50	0.68	5.16	22.17	1.00	1147.92	3.75
275	wheat	0.92	3.88	6.44	15.69	0.42	2.44	9.25	0.61	219.06	5.88	6.31	30.06	0.65	4.76	23.75	0.97	1145.94	4.25
276	wheat	0.22	4.31	6.94	14.56	0.35	2.10	7.63	0.52	131.88	5.75	5.25	29.19	0.70	5.56	23.94	1.03	1244.38	3.94
277	wheat	0.08	4.50	7.25	15.08	0.35	2.08	7.83	0.51	130.42	6.25	6.42	27.25	0.62	4.25	20.83	0.91	1025.83	4.75
278	wheat	0.11	4.50	7.13	14.75	0.35	2.07	7.63	0.51	131.88	6.00	6.06	27.94	0.64	4.61	21.88	0.95	1087.81	4.63
279	wheat	0.41	4.00	6.63	14.88	0.38	2.25	8.25	0.56	163.13	5.50	4.75	28.50	0.71	6.00	23.75	1.06	1258.75	4.00
280	wheat	0.08	4.00	6.25	15.00	0.41	2.40	8.75	0.60	223.75	5.50	4.75	29.50	0.72	6.21	24.75	1.07	1308.75	3.88
281	wheat	0.07	4.25	7.00	14.92	0.36	2.13	7.92	0.53	134.58	5.92	5.50	27.25	0.66	4.95	21.75	0.98	1127.08	4.17
282	wheat	0.26	4.25	7.25	15.38	0.36	2.12	8.13	0.53	121.25	5.88	5.69	29.06	0.67	5.11	23.38	0.99	1186.56	4.19
283	wheat	0.34	4.25	7.00	16.00	0.39	2.29	9.00	0.57	188.75	5.50	4.75	30.25	0.73	6.37	25.50	1.08	1346.25	4.00
284	wheat	0.86	3.92	6.75	14.08	0.35	2.09	7.33	0.52	97.50	5.50	5.08	29.67	0.71	5.84	24.58	1.05	1268.76	3.92
285	wheat	0.84	4.00	7.13	14.50	0.34	2.04	7.38	0.50	71.88	5.75	6.50	27.75	0.62	4.27	21.25	0.92	991.25	4.00
286	wheat	0.25	4.08	6.42	13.25	0.35	2.06	6.83	0.51	120.00	5.50	5.50	28.75	0.68	5.23	23.25	1.00	1162.50	3.83
287	wheat	0.74	4.25	7.00	14.25	0.34	2.04	7.25	0.50	101.25	6.00	5.88	27.50	0.65	4.68	21.63	0.96	1093.13	4.25
288	wheat	0.27	4.20	6.95	14.60	0.35	2.10	7.65	0.52	121.25	5.75	5.30	29.75	0.70	5.61	24.45	1.03	1265.25	4.25
289	wheat	0.62	4.00	6.25	15.75	0.43	2.52	9.50	0.63	261.25	5.50	6.25	32.00	0.67	5.12	25.75	1.00	1216.25	4.75
290	wheat	0.58	4.25	7.00	13.75	0.33	1.96	6.75	0.48	76.25	6.25	6.25	25.50	0.61	4.08	19.25	0.90	962.50	4.25
291	wheat	0.27	4.25	7.00	14.75	0.36	2.11	7.75	0.52	126.25	6.00	5.88	28.75	0.66	4.89	22.88	0.98	1155.63	4.25
292	wheat	0.25	4.25	7.25	14.50	0.33	2.00	7.25	0.49	77.50	5.75	5.50	29.25	0.68	5.32	23.75	1.01	1211.25	4.25
293	wheat	0.18	4.25	6.50	16.38	0.43	2.52	9.88	0.63	280.00	5.25	4.75	31.88	0.74	6.71	27.13	1.10	1403.75	3.88
294	wheat	0.11	4.25	6.75	16.00	0.41	2.37	9.25	0.60	225.00	5.50	4.75	29.50	0.72	6.21	24.75	1.07	1308.75	3.88
295	wheat	0.66	4.25	7.00	14.75	0.36	2.11	7.75	0.52	126.25	6.25	6.25	26.50	0.62	4.24	20.25	0.91	1012.50	4.25
296	wheat	1.29	3.25	6.00	15.00	0.43	2.50	9.00	0.63	188.75	5.75	6.75	30.25	0.64	4.48	23.50	0.94	1080.00	4.25
297	wheat	0.39	4.38	7.13	14.63	0.34	2.05	7.50	0.51	113.75	6.00	6.25	27.13	0.63	4.34	20.88	0.92	1020.00	4.50
298	wheat	0.17	4.50	7.00	15.00	0.36	2.14	8.00	0.53	162.50	6.25	5.50	27.25	0.66	4.95	21.75	0.98	1158.75	4.25
299	wheat	0.51	4.08	6.75	13.67	0.34	2.02	6.92	0.50	92.50	5.75	5.50	28.50	0.68	5.18	23.00	1.00	1173.75	4.25
317	wheat	0.05	4.19	5.63	20.38	0.57	3.62	14.75	0.83	600.94	5.81	3.75	39.75	0.83	10.60	36.00	1.23	1995.94	3.88
318	wheat	0.10	3.92	5.00	19.58	0.59	3.92	14.58	0.87	626.25	6.50	3.83	37.25	0.81	9.72	33.42	1.21	1924.17	4.00
319	wheat	0.14	3.75	5.00	16.69	0.54	3.34	11.69	0.79	465.63	4.88	3.81	36.06	0.81	9.46	32.25	1.20	1713.44	4.06
320	wheat	0.10	4.00	5.13	19.50	0.58	3.80	14.38	0.86	611.88	4.88	4.25	32.38	0.77	7.62	28.13	1.14	1465.63	3.63
321	wheat	0.17	4.25	6.25	16.75	0.46	2.68	10.50	0.67	335.00	5.63	4.63	27.69	0.71	5.99	23.06	1.05	1248.13	4.19
322	wheat	0.07	3.67	4.75	20.25	0.62	4.26	15.50	0.91	672.08	5.42	4.00	31.00	0.77	7.75	27.00	1.14	1484.58	3.75
323	wheat	0.92	4.00	6.00	19.50	0.53	3.25	13.50	0.78	485.00	5.50	4.25	30.75	0.76	7.24	26.50	1.12	1443.75	3.25
324	wheat	1.09	4.06	5.94	17.81	0.50	3.00	11.88	0.73	415.63	4.50	4.25	31.19	0.76	7.34	26.94	1.12	1370.63	3.63
325	wheat	0.52	4.00	6.00	17.75	0.49	2.96	11.75	0.73	397.50	5.25	3.50	30.75	0.80	8.79	27.25	1.18	1528.75	4.00
326	wheat	1.15	3.75	5.75	17.58	0.51	3.06	11.83	0.74	401.67	5.33	4.00	31.00	0.77	7.75	27.00	1.14	1476.67	3.42
327	wheat	0.13	4.25	6.25	18.58	0.50	2.97	12.33	0.73	426.67	5.00	4.25	32.79	0.77	7.72	28.54	1.14	1498.34	3.88
328	wheat	0.89	3.83	5.33	17.00	0.52	3.19	11.67	0.77	440.83	4.50	3.67	31.67	0.79	8.64	28.00	1.17	1479.17	3.42
329	wheat	0.52	3.81	5.19	17.75	0.55	3.42	12.56	0.80	497.50	4.50	3.75	35.13	0.81	9.37	31.38	1.20	1640.00	3.38
330	wheat	0.25	4.13	6.21	20.21	0.53	3.26	14.00	0.78	502.08	5.33	4.25	31.71	0.76	7.46	27.46	1.13	1475.83	3.79
331	wheat	1.01	4.00	6.00	16.81	0.47	2.80	10.81	0.70	350.63	4.88	4.25	29.94	0.75	7.04	25.69	1.11	1343.75	3.81
332	wheat	0.85	4.00	5.25	19.00	0.57	3.62	13.75	0.83	568.75	5.13	4.13	31.00	0.77	7.52	26.88	1.13	1438.75	3.88
333	wheat	1.01	3.75	5.50	18.50	0.54	3.36	13.00	0.80	483.75	5.25	3.50	31.00	0.80	8.86	27.50	1.18	1541.25	3.75
334	wheat	0.95	3.75	5.50	19.63	0.56	3.57	14.13	0.83	540.00	4.63	4.00	32.00	0.78	8.00	28.00	1.15	1459.38	3.50
335	wheat	1.10	3.25	4.75	18.00	0.58	3.79	13.25	0.85	520.00	5.00	4.00	31.00	0.77	7.75	27.00	1.14	1445.00	3.25
336	wheat	1.00	3.40	5.00	20.00	0.60	4.00	15.00	0.88	598.00	5.05	3.70	32.85	0.80	8.88	29.15	1.18	1585.75	3.25
337	wheat	0.06	3.75	6.00	18.50	0.51	3.08	12.50	0.75	411.25	5.25	5.00	28.25	0.70	5.65	23.25	1.03	1186.25	3.75

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
338	wheat	0.34	3.67	4.92	16.42	0.54	3.34	11.50	0.79	456.25	4.50	3.50	34.58	0.82	9.88	31.08	1.21	1649.16	4.17
339	wheat	0.49	3.75	5.25	17.75	0.54	3.38	12.50	0.80	482.50	5.50	4.25	26.75	0.73	6.29	22.50	1.07	1243.75	4.00
340	wheat	0.33	4.25	6.25	21.75	0.55	3.48	15.50	0.82	585.00	4.50	4.25	35.50	0.79	8.35	31.25	1.16	1586.25	4.00
341	wheat	0.95	4.00	6.25	18.25	0.49	2.92	12.00	0.72	386.25	5.75	4.25	30.00	0.75	7.06	25.75	1.11	1430.00	4.00
342	wheat	1.01	4.50	7.50	17.25	0.39	2.30	9.75	0.58	202.50	6.25	4.75	31.75	0.74	6.68	27.00	1.09	1492.50	3.75
343	wheat	1.09	5.08	7.67	18.08	0.40	2.36	10.42	0.60	275.41	6.00	5.00	34.08	0.74	6.82	29.08	1.10	1549.16	4.08
344	wheat	1.18	5.00	7.50	19.00	0.43	2.53	11.50	0.64	337.50	5.50	5.25	33.50	0.73	6.38	28.25	1.08	1436.25	3.75
345	wheat	1.13	5.50	8.25	18.88	0.39	2.29	10.63	0.58	270.00	6.50	5.50	33.13	0.72	6.02	27.63	1.06	1476.25	4.25
346	wheat	1.23	5.88	8.56	19.25	0.38	2.25	10.69	0.57	279.06	6.38	5.13	33.75	0.74	6.59	28.63	1.09	1550.00	4.25
347	wheat	0.16	2.25	4.25	19.75	0.65	4.65	15.50	0.95	585.00	8.25	7.25	29.75	0.61	4.10	22.50	0.90	1220.00	5.25
348	wheat	1.06	5.25	8.25	18.44	0.38	2.23	10.19	0.56	224.38	6.25	4.75	34.06	0.76	7.17	29.31	1.12	1608.13	3.75
349	wheat	0.86	5.17	8.25	18.75	0.39	2.27	10.50	0.57	232.08	5.75	5.25	30.50	0.71	5.81	25.25	1.04	1310.00	4.42
350	wheat	0.39	5.25	8.00	18.25	0.39	2.28	10.25	0.57	251.25	7.50	6.75	31.75	0.65	4.70	25.00	0.96	1321.25	4.25
351	wheat	1.05	4.50	7.75	16.50	0.36	2.13	8.75	0.53	128.75	6.25	4.75	32.00	0.74	6.74	27.25	1.10	1505.00	3.75
352	wheat	1.10	5.25	7.75	18.00	0.40	2.32	10.25	0.59	275.00	6.25	4.75	33.75	0.75	7.11	29.00	1.12	1592.50	4.25
353	wheat	0.82	4.75	8.00	18.75	0.40	2.34	10.75	0.59	228.75	5.50	4.75	33.50	0.75	7.05	28.75	1.11	1508.75	4.25
354	wheat	1.23	5.00	8.25	18.75	0.39	2.27	10.50	0.57	216.25	5.50	4.75	32.25	0.74	6.79	27.50	1.10	1446.25	3.75
355	wheat	1.00	5.13	8.38	19.88	0.41	2.37	11.50	0.60	266.25	6.50	5.50	32.13	0.71	5.84	26.63	1.05	1426.25	4.50
357	wheat	1.07	5.17	7.67	19.00	0.42	2.48	11.33	0.63	329.17	5.67	4.75	35.92	0.77	7.56	31.17	1.14	1645.42	4.00
358	wheat	0.43	5.00	7.88	18.63	0.41	2.37	10.75	0.60	264.38	6.25	5.50	33.50	0.72	6.09	28.00	1.06	1471.25	4.25
359	wheat	1.04	5.25	8.00	18.25	0.39	2.28	10.25	0.57	251.25	6.00	4.75	34.25	0.76	7.21	29.50	1.12	1593.75	4.00
383	wheat	1.24	5.25	8.00	19.25	0.41	2.41	11.25	0.61	301.25	6.00	4.75	34.00	0.75	7.16	29.25	1.12	1581.25	4.00
384	wheat	1.11	5.50	8.25	20.75	0.43	2.52	12.50	0.64	363.75	6.00	6.75	35.00	0.68	5.19	28.25	1.00	1341.25	4.00
385	wheat	1.10	6.25	8.75	20.00	0.39	2.29	11.25	0.58	325.00	7.00	6.75	34.25	0.67	5.07	27.50	0.99	1398.75	4.00
386	wheat	1.17	5.75	8.38	20.13	0.41	2.40	11.75	0.61	338.13	7.25	6.25	34.38	0.69	5.50	28.13	1.03	1501.25	4.00
387	wheat	0.81	5.25	8.00	19.75	0.42	2.47	11.75	0.62	326.25	6.00	4.75	34.00	0.75	7.16	29.25	1.12	1581.25	3.75
388	wheat	0.96	5.00	8.00	20.00	0.43	2.50	12.00	0.63	315.00	6.00	5.25	37.50	0.75	7.14	32.25	1.12	1683.75	3.75
389	wheat	1.20	6.25	8.63	19.75	0.39	2.29	11.13	0.58	330.63	7.50	6.00	34.00	0.70	5.67	28.00	1.04	1542.50	4.00
390	wheat	1.13	6.00	8.50	21.00	0.42	2.47	12.50	0.63	387.50	6.00	6.00	34.75	0.71	5.79	28.75	1.05	1437.50	4.00
391	wheat	1.12	5.58	8.33	19.67	0.40	2.36	11.33	0.60	305.42	6.00	5.17	34.67	0.74	6.71	29.50	1.10	1554.17	4.00
392	wheat	0.92	5.25	8.25	19.50	0.41	2.36	11.25	0.60	277.50	6.00	4.75	34.00	0.75	7.16	29.25	1.12	1581.25	3.75
393	wheat	0.81	5.50	8.25	19.75	0.41	2.39	11.50	0.61	313.75	6.00	4.75	33.00	0.75	6.95	28.25	1.11	1531.25	4.00
394	wheat	1.22	5.75	8.50	20.75	0.42	2.44	12.25	0.62	351.25	6.75	5.50	34.38	0.72	6.25	28.88	1.07	1562.50	4.00
395	wheat	1.26	5.00	7.50	20.50	0.46	2.73	13.00	0.68	412.50	6.00	6.25	34.75	0.70	5.56	28.50	1.03	1401.25	4.00
397	wheat	1.05	5.00	7.50	20.50	0.46	2.73	13.00	0.68	412.50	5.75	4.75	37.13	0.77	7.82	32.38	1.15	1713.75	3.75
398	wheat	1.18	5.50	8.50	20.50	0.41	2.41	12.00	0.61	315.00	6.00	4.75	36.00	0.77	7.58	31.25	1.14	1681.25	4.00
399	wheat	0.87	5.00	7.83	18.92	0.41	2.41	11.08	0.61	285.00	5.67	4.92	34.75	0.75	7.07	29.83	1.11	1562.92	3.92
400	wheat	0.83	5.25	8.25	19.50	0.41	2.36	11.25	0.60	277.50	5.50	5.00	34.88	0.75	6.98	29.88	1.11	1541.25	4.00
401	wheat	0.65	4.00	6.38	13.13	0.35	2.06	6.75	0.51	111.88	6.50	6.38	25.38	0.60	3.98	19.00	0.88	961.88	5.75
402	wheat	0.40	3.94	6.38	13.19	0.35	2.07	6.81	0.51	109.06	6.06	6.19	25.75	0.61	4.16	19.56	0.90	966.25	5.88
403	wheat	1.09	3.83	6.50	12.75	0.32	1.96	6.25	0.47	59.17	7.00	7.08	22.58	0.52	3.19	15.50	0.77	767.08	6.00
404	wheat	0.91	4.00	6.63	13.50	0.34	2.04	6.88	0.50	94.38	6.25	6.38	26.13	0.61	4.10	19.75	0.90	975.63	5.38
405	wheat	0.06	3.94	6.44	13.19	0.34	2.05	6.75	0.50	100.00	6.75	6.69	23.75	0.56	3.55	17.06	0.83	859.06	6.00
406	wheat	0.19	4.13	6.63	13.13	0.33	1.98	6.50	0.48	87.50	7.50	7.50	23.50	0.52	3.13	16.00	0.76	800.00	5.50
407	wheat	0.08	4.08	6.58	13.42	0.34	2.04	6.83	0.50	104.17	7.17	7.00	25.08	0.56	3.58	18.08	0.83	920.00	5.75
408	wheat	1.08	4.08	6.92	13.92	0.34	2.01	7.00	0.49	80.83	6.50	6.92	25.75	0.58	3.72	18.83	0.85	902.08	5.25
409	wheat	1.21	4.13	7.00	13.50	0.32	1.93	6.50	0.46	51.88	6.63	7.63	22.75	0.50	2.98	15.13	0.73	661.25	6.00
410	wheat	1.44	4.25	7.13	14.38	0.34	2.02	7.25	0.49	89.38	6.00	6.75	27.00	0.60	4.00	20.25	0.89	941.25	5.75

Appendix I: Yield Map and Satellite Parameter Database

AOI ID	CROP	Yield	181-1	181-2	181-3	181NDVI	181 RVI	181 DVI	181 SAVI	181 TVI	221-1	221-2	221-3	221NDVI	221 RVI	221 DVI	221 SAVI	221 TVI	240-1
411	wheat	1.22	4.25	6.75	13.75	0.34	2.04	7.00	0.50	112.50	7.00	6.75	26.00	0.59	3.85	19.25	0.87	986.25	5.75
412	wheat	0.99	3.88	6.25	13.75	0.38	2.20	7.50	0.55	149.38	6.00	6.25	27.13	0.63	4.34	20.88	0.92	1020.00	5.88
413	wheat	0.60	4.00	6.67	13.67	0.34	2.05	7.00	0.50	96.67	6.67	7.25	25.75	0.56	3.55	18.50	0.83	869.58	6.00
414	wheat	1.07	3.75	6.25	13.38	0.36	2.14	7.13	0.53	118.75	6.50	6.50	25.50	0.59	3.92	19.00	0.88	950.00	6.00
415	wheat	1.05	3.88	6.50	12.63	0.32	1.94	6.13	0.47	56.88	7.00	7.00	24.00	0.55	3.43	17.00	0.81	850.00	5.88
416	wheat	0.38	4.13	6.94	13.19	0.31	1.90	6.25	0.45	45.31	6.00	7.31	24.38	0.54	3.33	17.06	0.80	728.44	5.75
417	wheat	0.37	4.00	6.58	13.25	0.34	2.01	6.67	0.49	87.92	6.33	7.33	23.67	0.53	3.23	16.33	0.78	721.67	5.83
418	wheat	0.74	4.00	6.33	13.25	0.35	2.09	6.92	0.52	124.17	7.00	7.00	24.92	0.56	3.56	17.92	0.83	895.83	5.83
419	wheat	0.69	3.75	6.38	13.38	0.35	2.10	7.00	0.52	100.63	7.00	6.50	24.50	0.58	3.77	18.00	0.86	947.50	5.88
420	wheat	1.07	4.00	6.58	13.17	0.33	2.00	6.58	0.49	83.75	7.00	6.50	23.75	0.57	3.65	17.25	0.84	910.00	5.92
421	wheat	0.24	4.00	6.50	12.50	0.32	1.92	6.00	0.46	62.50	7.25	7.63	21.75	0.48	2.85	14.13	0.71	670.63	5.88
423	wheat	1.28	4.00	6.63	12.63	0.31	1.91	6.00	0.46	50.63	7.00	7.13	23.13	0.53	3.25	16.00	0.78	788.13	5.88
424	wheat	0.84	4.10	6.70	12.80	0.31	1.91	6.10	0.46	58.00	6.55	6.85	21.70	0.52	3.17	14.85	0.77	714.00	5.75
425	wheat	0.95	3.75	6.08	12.58	0.35	2.07	6.50	0.51	103.33	6.25	5.58	24.00	0.62	4.30	18.42	0.92	984.17	5.42
426	wheat	0.99	4.25	7.00	14.33	0.34	2.05	7.33	0.50	105.42	7.00	7.08	25.58	0.57	3.61	18.50	0.84	917.08	5.75
427	wheat	0.30	4.25	6.75	13.83	0.34	2.05	7.08	0.50	116.67	7.00	7.33	24.75	0.54	3.38	17.42	0.80	839.17	5.83
428	wheat	0.20	3.63	6.13	11.75	0.31	1.92	5.63	0.46	43.75	7.00	8.00	21.75	0.46	2.72	13.75	0.68	592.50	5.88
429	wheat	1.12	3.75	6.75	12.75	0.31	1.89	6.00	0.45	15.00	6.00	6.75	23.67	0.56	3.51	16.92	0.82	774.58	5.75
430	wheat	1.08	4.00	6.50	12.50	0.32	1.92	6.00	0.46	62.50	7.00	6.75	23.50	0.55	3.48	16.75	0.82	861.25	6.00
431	wheat	0.04	4.13	6.69	12.81	0.31	1.92	6.13	0.46	62.81	7.50	8.00	22.56	0.48	2.82	14.56	0.70	680.63	6.25
432	wheat	0.02	4.17	6.58	13.58	0.35	2.06	7.00	0.51	120.42	7.17	7.17	25.42	0.56	3.55	18.25	0.83	912.50	5.50
433	wheat	0.15	4.00	6.75	13.50	0.33	2.00	6.75	0.49	76.25	7.00	8.00	25.25	0.52	3.16	17.25	0.77	767.50	5.63
446	wheat	1.16	4.75	7.25	17.00	0.40	2.34	9.75	0.59	250.00	6.00	4.75	33.75	0.75	7.11	29.00	1.12	1568.75	3.75
447	wheat	0.91	4.50	7.00	16.50	0.40	2.36	9.50	0.59	237.50	6.00	3.75	31.75	0.79	8.47	28.00	1.17	1613.75	3.75
448	wheat	1.19	5.17	7.67	19.58	0.44	2.55	11.92	0.64	358.33	5.67	4.92	34.75	0.75	7.07	29.83	1.11	1562.92	3.75
449	wheat	1.11	5.00	7.25	17.75	0.42	2.45	10.50	0.62	311.25	6.00	4.75	33.75	0.75	7.11	29.00	1.12	1568.75	3.75
450	wheat	1.02	4.88	7.25	19.13	0.45	2.64	11.88	0.66	368.13	6.00	5.00	34.00	0.74	6.80	29.00	1.10	1545.00	3.88
451	wheat	1.03	5.38	7.25	20.00	0.47	2.76	12.75	0.69	459.38	5.50	4.75	34.00	0.75	7.16	29.25	1.12	1533.75	3.88
452	wheat	1.23	5.38	7.75	19.75	0.44	2.55	12.00	0.64	374.38	5.50	4.00	35.75	0.80	8.94	31.75	1.18	1730.00	3.88
453	wheat	1.24	4.63	7.13	17.50	0.42	2.46	10.38	0.62	281.25	5.50	4.25	32.00	0.77	7.53	27.75	1.13	1506.25	3.88
454	wheat	1.25	4.50	6.83	18.00	0.45	2.63	11.17	0.66	336.67	5.67	5.08	34.25	0.74	6.74	29.17	1.10	1513.75	3.75
455	wheat	0.91	4.25	7.00	17.25	0.42	2.46	10.25	0.62	251.25	5.50	3.25	31.50	0.81	9.69	28.25	1.20	1626.25	4.75
456	wheat	0.92	4.25	6.75	17.50	0.44	2.59	10.75	0.65	300.00	5.25	3.75	29.75	0.78	7.93	26.00	1.15	1442.50	3.00
457	wheat	0.82	4.50	6.75	17.50	0.44	2.59	10.75	0.65	323.75	4.75	4.75	29.75	0.72	6.26	25.00	1.07	1250.00	3.00
594	wheat	1.25	5.00	7.67	16.50	0.37	2.15	8.83	0.54	188.33	6.50	6.42	29.08	0.64	4.53	22.67	0.94	1141.24	4.25
595	wheat	0.94	5.42	9.00	18.50	0.35	2.06	9.50	0.51	134.58	6.33	5.17	32.83	0.73	6.35	27.67	1.08	1494.16	3.83

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
62	4.20	56.85	0.86	13.54	52.65	1.28	2803.50	6.80	4.50	58.60	0.86	13.02	54.10	1.28	2923.50	6.35	4.80	50.30	0.83
63	7.04	38.08	0.69	5.41	31.04	1.02	1587.70	8.54	7.42	38.75	0.68	5.22	31.33	1.01	1673.54	7.00	5.63	44.71	0.78
64	4.43	49.50	0.84	11.18	45.07	1.24	2450.36	6.93	4.61	55.00	0.85	11.94	50.39	1.26	2740.18	6.46	5.00	47.50	0.81
65	4.69	54.69	0.84	11.67	50.00	1.25	2648.44	7.00	4.75	54.44	0.84	11.46	49.69	1.25	2698.13	6.31	5.13	45.19	0.80
66	7.20	32.30	0.64	4.49	25.10	0.94	1264.50	7.90	7.15	36.40	0.67	5.09	29.25	1.00	1533.75	6.70	5.25	43.55	0.78
67	4.50	51.25	0.84	11.39	46.75	1.25	2489.50	6.85	4.60	55.55	0.85	12.08	50.95	1.26	2761.25	6.70	5.10	47.05	0.80
68	4.69	57.69	0.85	12.31	53.00	1.26	2774.69	7.00	5.13	56.13	0.83	10.95	51.00	1.24	2728.13	6.50	5.13	48.44	0.81
69	4.50	54.31	0.85	12.07	49.81	1.26	2645.00	7.00	4.56	56.19	0.85	12.32	51.63	1.26	2812.81	6.50	5.00	47.63	0.81
70	4.25	54.94	0.86	12.93	50.69	1.27	2700.63	7.13	5.00	55.88	0.84	11.18	50.88	1.24	2745.63	6.38	5.06	43.94	0.79
71	4.58	50.79	0.83	11.08	46.21	1.24	2452.92	7.00	4.67	53.92	0.84	11.55	49.25	1.25	2684.17	6.46	4.92	47.46	0.81
107	3.75	50.50	0.86	13.47	46.75	1.28	2480.00	7.50	5.50	52.75	0.81	9.59	47.25	1.21	2552.50	7.00	5.00	47.75	0.81
108	4.06	52.00	0.86	12.80	47.94	1.27	2509.69									6.81	5.63	44.75	0.78
109	4.25	54.75	0.86	12.88	50.50	1.27	2596.25	7.75	6.00	57.63	0.81	9.60	51.63	1.21	2747.50	6.75	5.38	47.75	0.80
110	3.75	56.50	0.88	15.07	52.75	1.30	2827.50	7.75	5.25	59.50	0.84	11.33	54.25	1.25	2950.00	7.25	5.00	48.75	0.81
111	3.75	55.50	0.87	14.80	51.75	1.30	2718.13	8.00	5.25	58.25	0.83	11.10	53.00	1.24	2911.25	6.75	5.00	49.00	0.81
112	3.75	54.38	0.87	14.50	50.63	1.30	2673.75	8.25	6.25	55.50	0.80	8.88	49.25	1.19	2652.50	6.50	5.13	44.00	0.79
113	4.00	49.25	0.85	12.31	45.25	1.26	2381.25	8.25	5.50	52.75	0.81	9.59	47.25	1.21	2623.75	7.00	5.00	44.50	0.80
114	4.00	52.75	0.86	13.19	48.75	1.28	2556.25	7.50	5.25	53.63	0.82	10.21	48.38	1.22	2632.50	6.75	5.13	43.75	0.79
115	3.88	54.13	0.87	13.97	50.25	1.29	2643.13									7.00	5.25	46.88	0.80
144	3.50	53.00	0.88	15.14	49.50	1.30	2641.25	8.25	5.25	53.25	0.82	10.14	48.00	1.22	2685.00	7.00	5.75	41.25	0.76
145	3.75	51.25	0.86	13.67	47.50	1.28	2517.50	7.75	5.50	53.00	0.81	9.64	47.50	1.21	2588.75	6.75	5.13	42.63	0.79
146	3.63	53.75	0.87	14.83	50.13	1.30	2684.38									6.50	5.00	44.13	0.80
147	3.75	51.17	0.86	13.64	47.42	1.28	2513.34	8.25	5.92	53.75	0.80	9.08	47.83	1.19	2613.33	6.83	5.25	43.67	0.79
148	5.00	47.75	0.81	9.55	42.75	1.20	2208.75	7.75	5.75	52.75	0.80	9.17	47.00	1.19	2540.00	6.50	5.75	40.00	0.75
149	4.00	51.75	0.86	12.94	47.75	1.27	2506.25	7.63	5.50	54.00	0.82	9.82	48.50	1.21	2626.88	6.50	5.75	46.25	0.78
150	3.75	53.50	0.87	14.27	49.75	1.29	2630.00	8.25	6.00	54.50	0.80	9.08	48.50	1.19	2638.75	7.00	5.25	44.75	0.79
151	3.50	54.25	0.88	15.50	50.75	1.31	2703.75	8.25	5.25	54.88	0.83	10.45	49.63	1.23	2766.25	6.75	5.00	43.63	0.79
153	4.25	53.00	0.85	12.47	48.75	1.27	2532.50	7.63	5.75	53.50	0.81	9.30	47.75	1.20	2565.63	6.38	5.50	41.38	0.77
154	3.83	49.08	0.86	12.80	45.25	1.27	2397.08	7.75	5.33	51.17	0.81	9.59	45.83	1.21	2521.26	6.83	5.83	38.75	0.74
155	3.75	48.25	0.86	12.87	44.50	1.27	2367.50	7.63	5.38	51.75	0.81	9.63	46.38	1.21	2532.50	7.00	5.75	40.75	0.75
156	4.50	46.75	0.82	10.39	42.25	1.22	2243.13	8.13	5.25	50.13	0.81	9.55	44.88	1.20	2516.88	7.00	6.00	41.00	0.74
157	4.50	47.00	0.83	10.44	42.50	1.23	2243.75	7.75	5.50	48.75	0.80	8.86	43.25	1.18	2376.25	7.50	6.00	43.00	0.76
158	3.88	48.50	0.85	12.52	44.63	1.27	2361.88	7.63	5.25	52.38	0.82	9.98	47.13	1.22	2581.88	7.00	5.63	40.63	0.76
159	3.75	52.50	0.87	14.00	48.75	1.29	2580.00	8.25	6.00	53.25	0.80	8.88	47.25	1.19	2576.25	6.50	5.25	44.25	0.79
170	5.38	40.75	0.77	7.58	35.38	1.14	1816.25	7.00	5.00	46.75	0.81	9.35	41.75	1.20	2277.50	6.25	5.25	40.25	0.77
171	5.06	29.06	0.70	5.74	24.00	1.04	1241.56	7.13	5.25	36.81	0.75	7.01	31.56	1.11	1756.25	6.44	5.88	35.31	0.71
172	6.42	21.17	0.53	3.30	14.75	0.79	721.67	7.67	6.25	28.17	0.64	4.51	21.92	0.94	1230.42	7.00	6.17	32.83	0.68
173	8.75	21.75	0.43	2.49	13.00	0.63	555.00	8.50	8.00	28.00	0.56	3.50	20.00	0.82	1047.50	8.00	7.25	39.25	0.69
174	7.50	38.75	0.68	5.17	31.25	1.00	1443.75	7.00	6.13	43.38	0.75	7.08	37.25	1.12	1945.63	6.25	5.50	40.00	0.76
175	7.75	26.50	0.55	3.42	18.75	0.81	913.75	7.63	6.50	39.25	0.72	6.04	32.75	1.06	1744.38	7.25	6.25	41.75	0.74
176	8.00	25.75	0.53	3.22	17.75	0.78	863.75	8.75	7.75	32.25	0.61	4.16	24.50	0.91	1320.00	7.38	6.63	35.50	0.69
177	7.00	29.75	0.62	4.25	22.75	0.92	1113.75	7.75	6.75	35.00	0.68	5.19	28.25	1.00	1507.50	6.50	5.63	39.00	0.75
178	10.00	21.00	0.35	2.10	11.00	0.52	360.00	9.25	11.00	24.00	0.37	2.18	13.00	0.55	483.75	8.00	8.50	30.50	0.56
179	8.63	25.75	0.50	2.99	17.13	0.74	725.63	8.50	9.25	29.75	0.53	3.22	20.50	0.78	953.75	7.25	6.75	37.00	0.69
180	9.25	22.00	0.41	2.38	12.75	0.60	495.00	8.75	9.25	22.50	0.42	2.43	13.25	0.62	615.00	7.75	7.50	29.50	0.59
181	9.50	24.88	0.45	2.62	15.38	0.66	566.88	8.75	9.38	29.00	0.51	3.09	19.63	0.76	921.88	7.50	7.13	34.50	0.66
182	7.75	30.83	0.60	3.98	23.08	0.89	1130.41	7.50	7.17	36.92	0.67	5.15	29.75	1.00	1519.17	6.75	6.00	40.00	0.74
183	7.75	33.00	0.62	4.26	25.25	0.92	1167.50	7.38	6.00	42.00	0.75	7.00	36.00	1.11	1930.63	7.13	6.00	45.13	0.77

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
184	8.75	21.50	0.42	2.46	12.75	0.62	471.25	9.00	9.25	25.00	0.46	2.70	15.75	0.68	763.75	7.25	7.25	31.25	0.62
221	4.00	47.00	0.84	11.75	43.00	1.25	2316.25	8.25	6.75	50.00	0.76	7.41	43.25	1.13	2305.00	7.00	5.75	43.50	0.77
222	4.00	46.50	0.84	11.63	42.50	1.25	2243.75	8.50	6.25	50.25	0.78	8.04	44.00	1.16	2413.75	7.00	5.25	41.75	0.78
223	4.00	55.50	0.87	13.88	51.50	1.29	2693.75	7.50	5.00	57.00	0.84	11.40	52.00	1.25	2837.50	6.50	5.25	47.00	0.80
224	3.75	53.50	0.87	14.27	49.75	1.29	2630.00	7.75	6.00	52.75	0.80	8.79	46.75	1.18	2503.75	7.00	5.00	46.75	0.81
225	3.50	54.25	0.88	15.50	50.75	1.31	2703.75	7.50	5.50	55.00	0.82	10.00	49.50	1.22	2665.00	7.00	5.25	46.25	0.80
300	4.50	56.17	0.85	12.48	51.67	1.27	2725.84	7.00	4.33	57.92	0.86	13.37	53.58	1.28	2932.51	6.50	4.83	48.75	0.82
301	4.00	55.33	0.87	13.83	51.33	1.29	2748.75	7.00	4.50	56.08	0.85	12.46	51.58	1.27	2816.66	6.33	5.00	47.00	0.81
302	4.56	57.63	0.85	12.63	53.06	1.27	2789.69	7.00	4.88	57.00	0.84	11.69	52.13	1.25	2808.13	6.63	5.19	47.50	0.80
303	5.69	39.00	0.75	6.86	33.31	1.11	1802.19	7.00	4.63	51.75	0.84	11.19	47.13	1.24	2581.88	6.88	5.19	48.06	0.81
304	4.50	57.50	0.85	12.78	53.00	1.27	2792.50	7.00	4.25	58.50	0.86	13.76	54.25	1.29	2973.75	6.50	5.25	46.75	0.80
305	3.75	58.25	0.88	15.53	54.50	1.31	2938.75	6.63	4.25	55.38	0.86	13.03	51.13	1.28	2781.88	6.50	5.13	46.75	0.80
306	4.25	57.17	0.86	13.45	52.92	1.28	2812.09	7.50	5.08	57.92	0.84	11.39	52.83	1.25	2871.26	6.50	4.75	47.50	0.82
307	5.08	48.83	0.81	9.61	43.75	1.21	2306.25									6.25	5.08	43.92	0.79
308	4.58	54.17	0.84	11.82	49.58	1.26	2685.01	7.00	4.67	56.83	0.85	12.18	52.17	1.26	2829.99	6.50	4.75	50.83	0.83
309	4.50	54.75	0.85	12.17	50.25	1.26	2726.25	7.00	4.75	49.75	0.83	10.47	45.00	1.23	2463.75	6.75	5.00	50.25	0.82
310	4.50	54.17	0.85	12.04	49.67	1.26	2649.59	6.67	4.50	56.67	0.85	12.59	52.17	1.27	2814.17	6.42	5.00	48.42	0.81
311	6.25	53.25	0.79	8.52	47.00	1.18	2350.00	7.00	5.38	54.75	0.82	10.19	49.38	1.22	2623.13	6.88	5.13	47.50	0.81
312	4.50	57.00	0.85	12.67	52.50	1.27	2759.58	7.00	4.50	57.42	0.85	12.76	52.92	1.27	2883.34	6.50	4.83	49.33	0.82
313	4.50	57.83	0.86	12.85	53.33	1.27	2809.16	7.00	4.58	56.83	0.85	12.40	52.25	1.27	2842.08	6.33	4.92	47.33	0.81
314	4.25	55.50	0.86	13.06	51.25	1.28	2776.25	6.75	4.25	57.00	0.86	13.41	52.75	1.28	2875.00	6.25	5.00	46.25	0.80
315	5.88	43.50	0.76	7.40	37.63	1.13	2023.75	8.38	7.50	41.13	0.69	5.48	33.63	1.03	1764.38	7.38	6.00	42.88	0.75
316	3.75	54.75	0.87	14.60	51.00	1.30	2763.75	7.00	4.50	56.00	0.85	12.44	51.50	1.27	2812.50	6.50	4.75	48.00	0.82
434	3.75	50.00	0.86	13.33	46.25	1.28	2455.00	7.75	5.50	51.50	0.81	9.36	46.00	1.20	2513.75	6.75	6.00	38.00	0.73
435	4.00	47.25	0.84	11.81	43.25	1.25	2328.75	7.75	4.88	53.00	0.83	10.87	48.13	1.24	2679.38	7.00	5.50	42.38	0.77
436	4.50	48.25	0.83	10.72	43.75	1.23	2306.25	7.75	5.00	47.75	0.81	9.55	42.75	1.20	2398.75	7.00	6.00	41.25	0.75
437	3.75	53.06	0.87	14.15	49.31	1.29	2608.13									6.50	5.13	45.44	0.80
438	3.83	52.42	0.86	13.67	48.58	1.28	2563.76	7.67	5.50	53.83	0.81	9.79	48.33	1.21	2622.50	6.50	5.17	42.75	0.78
439	4.50	47.75	0.83	10.61	43.25	1.23	2281.25	7.50	5.50	51.25	0.81	9.32	45.75	1.20	2477.50	6.50	5.25	40.00	0.77
440	3.50	53.00	0.88	15.14	49.50	1.30	2688.75	7.50	5.25	54.92	0.83	10.46	49.67	1.23	2697.09	6.67	5.17	42.92	0.79
441	3.63	51.00	0.87	14.07	47.38	1.29	2499.38	7.38	5.13	54.75	0.83	10.68	49.63	1.23	2695.00	6.50	5.00	42.75	0.79
442	3.63	53.75	0.87	14.83	50.13	1.30	2660.63									7.00	4.88	46.63	0.81
443	4.25	48.50	0.84	11.41	44.25	1.25	2307.50	7.50	5.50	51.50	0.81	9.36	46.00	1.20	2490.00	6.50	5.75	44.63	0.77
444	3.50	53.00	0.88	15.14	49.50	1.30	2641.25									6.50	5.25	44.50	0.79
445	3.75	50.75	0.86	13.53	47.00	1.28	2540.00	7.75	5.25	53.50	0.82	10.19	48.25	1.22	2650.00	7.00	6.00	40.00	0.74
458	7.92	27.92	0.56	3.53	20.00	0.83	936.67	7.75	6.92	36.83	0.68	5.33	29.92	1.01	1574.99	7.00	6.42	37.75	0.71
459	9.13	25.38	0.47	2.78	16.25	0.70	658.13	8.25	8.13	31.75	0.59	3.91	23.63	0.88	1193.13	7.25	6.50	37.13	0.70
461	8.75	26.50	0.50	3.03	17.75	0.74	768.75	7.50	7.25	35.50	0.66	4.90	28.25	0.98	1436.25	7.25	6.50	38.00	0.71
462	8.50	30.00	0.56	3.53	21.50	0.83	1003.75	9.00	9.75	27.50	0.48	2.82	17.75	0.71	816.25	7.50	8.00	33.25	0.61
463	8.33	27.25	0.53	3.27	18.92	0.79	882.50	8.58	7.67	33.67	0.63	4.39	26.00	0.93	1387.09	7.00	6.50	38.75	0.71
464	6.00	33.75	0.70	5.63	27.75	1.03	1482.50	8.00	6.38	32.00	0.67	5.02	25.63	0.99	1435.63	6.50	5.75	38.13	0.74
465	6.19	41.38	0.74	6.69	35.19	1.10	1741.56	6.75	5.38	50.94	0.81	9.48	45.56	1.20	2408.75	6.13	5.75	45.38	0.78
466	8.00	30.25	0.58	3.78	22.25	0.86	1029.38	7.50	6.38	38.75	0.72	6.08	32.38	1.06	1725.63	7.13	6.25	40.88	0.73
467	8.75	24.75	0.48	2.83	16.00	0.71	681.25	7.75	8.00	32.00	0.60	4.00	24.00	0.89	1176.25	7.50	6.50	43.63	0.74
468	9.50	21.69	0.39	2.28	12.19	0.58	443.13	9.00	9.88	25.94	0.45	2.63	16.06	0.66	720.00	7.44	7.13	36.50	0.67
470	9.00	22.50	0.43	2.50	13.50	0.63	580.00	9.00	9.25	26.50	0.48	2.86	17.25	0.71	838.75	7.50	7.00	34.00	0.66
471	7.75	43.25	0.70	5.58	35.50	1.03	1775.00	7.50	6.75	42.25	0.72	6.26	35.50	1.08	1846.25	7.75	7.75	44.00	0.70
472	8.50	23.00	0.46	2.71	14.50	0.68	653.75	8.75	7.63	28.50	0.58	3.74	20.88	0.85	1150.63	7.75	6.50	41.25	0.73

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
473	6.13	38.50	0.73	6.29	32.38	1.08	1642.50	6.75	4.63	46.38	0.82	10.03	41.75	1.22	2289.38	5.88	4.75	41.00	0.79
474	5.75	39.75	0.75	6.91	34.00	1.11	1723.75	6.25	5.25	46.50	0.80	8.86	41.25	1.18	2157.50	6.00	4.75	40.75	0.79
475	5.50	38.25	0.75	6.95	32.75	1.11	1685.00	6.75	5.25	46.50	0.80	8.86	41.25	1.18	2205.00	6.25	5.13	41.00	0.78
476	8.63	23.31	0.46	2.70	14.69	0.68	716.56	9.00	7.81	27.69	0.56	3.54	19.88	0.83	1106.56	7.75	6.50	41.38	0.73
477	5.83	24.42	0.61	4.19	18.58	0.91	921.25	7.50	5.75	33.17	0.70	5.77	27.42	1.04	1537.09	7.00	6.17	37.50	0.72
478	5.75	24.75	0.62	4.30	19.00	0.92	950.00	7.25	5.63	31.25	0.69	5.56	25.63	1.03	1435.63	7.13	6.00	36.00	0.71
479	5.75	34.00	0.71	5.91	28.25	1.05	1531.25	8.00	5.50	39.63	0.76	7.20	34.13	1.12	1943.75	6.13	5.00	41.38	0.78
480	8.00	33.25	0.61	4.16	25.25	0.91	1167.50	8.50	7.50	35.25	0.65	4.70	27.75	0.96	1482.50	7.75	6.50	45.00	0.75
481	6.25	38.50	0.72	6.16	32.25	1.07	1588.75	6.25	5.38	43.38	0.78	8.07	38.00	1.16	1983.13	6.00	5.00	39.75	0.78
482	5.88	40.75	0.75	6.94	34.88	1.11	1755.63	6.50	5.63	46.50	0.78	8.27	40.88	1.17	2126.88	6.25	5.88	42.25	0.76
483	6.00	35.75	0.71	5.96	29.75	1.06	1487.50	6.50	5.00	44.00	0.80	8.80	39.00	1.18	2092.50	6.25	5.25	40.00	0.77
484	5.75	22.00	0.59	3.83	16.25	0.86	812.50	7.75	6.00	31.75	0.68	5.29	25.75	1.01	1453.75	7.25	6.50	36.75	0.70
485	5.75	21.00	0.57	3.65	15.25	0.84	833.75	7.75	5.75	28.75	0.67	5.00	23.00	0.99	1340.00	7.25	6.25	35.00	0.70
486	5.63	41.00	0.76	7.29	35.38	1.13	1851.88	6.75	4.50	53.75	0.85	11.94	49.25	1.26	2676.25	6.25	5.00	48.13	0.81
487	5.50	25.00	0.64	4.55	19.50	0.94	1070.00	7.50	5.25	35.00	0.74	6.67	29.75	1.10	1701.25	6.50	6.25	38.75	0.72
488	9.25	24.38	0.45	2.64	15.13	0.66	613.75	8.88	9.13	28.25	0.51	3.10	19.13	0.76	932.50	7.13	6.88	35.00	0.67
489	5.88	35.00	0.71	5.96	29.13	1.06	1420.63	7.50	6.13	42.63	0.75	6.96	36.50	1.11	1955.63	6.81	7.06	38.56	0.69
490	8.25	31.50	0.58	3.82	23.25	0.87	1138.75	7.50	6.13	40.88	0.74	6.67	34.75	1.10	1868.13	7.63	6.63	43.38	0.74
498	4.50	54.75	0.85	12.17	50.25	1.26	2583.75	8.50	6.75	58.75	0.79	8.70	52.00	1.18	2766.25	6.50	5.25	47.75	0.80
499	6.00	43.75	0.76	7.29	37.75	1.13	1911.25	7.75	6.13	52.88	0.79	8.63	46.75	1.18	2491.88	6.75	6.50	41.88	0.73
500	3.75	50.00	0.86	13.33	46.25	1.28	2455.00	7.75	5.50	54.50	0.82	9.91	49.00	1.21	2663.75	6.50	4.75	42.00	0.80
501	3.67	55.08	0.88	15.02	51.42	1.30	2768.74	7.75	5.00	59.17	0.84	11.83	54.17	1.26	2969.59	7.00	4.92	49.17	0.82
502	3.63	56.25	0.88	15.52	52.63	1.31	2809.38	8.00	5.13	58.88	0.84	11.49	53.75	1.25	2960.63	7.25	5.00	48.63	0.81
503	3.83	53.58	0.87	13.98	49.75	1.29	2630.00	7.92	5.17	58.92	0.84	11.40	53.75	1.25	2948.75	7.08	5.00	47.00	0.81
504	3.50	54.08	0.88	15.45	50.58	1.31	2711.25	7.63	5.08	57.79	0.84	11.37	52.71	1.25	2876.88	7.00	5.21	47.67	0.80
505	3.81	52.06	0.86	13.66	48.25	1.28	2549.06	7.75	5.75	51.63	0.80	8.98	45.88	1.19	2483.75	7.00	5.06	44.13	0.79
506	4.00	54.75	0.86	13.69	50.75	1.28	2656.25	7.75	5.50	56.50	0.82	10.27	51.00	1.22	2763.75	7.00	4.75	46.75	0.82
507	3.60	50.40	0.87	14.00	46.80	1.29	2496.75	8.70	6.65	53.20	0.78	8.00	46.55	1.16	2522.25	6.80	5.15	43.95	0.79
508	3.75	54.67	0.87	14.58	50.92	1.30	2656.67	8.08	6.00	55.67	0.81	9.28	49.67	1.20	2681.25	6.75	5.00	45.25	0.80
509	4.50	42.63	0.81	9.47	38.13	1.20	2001.25	7.63	5.00	58.25	0.84	11.65	53.25	1.25	2911.88	6.75	5.38	41.50	0.77
510	4.60	53.85	0.84	11.71	49.25	1.25	2519.50									6.60	6.10	45.05	0.76
511	4.92	53.67	0.83	10.92	48.75	1.24	2485.00									6.42	6.08	45.17	0.76
512	3.75	52.50	0.87	14.00	48.75	1.29	2580.00	8.50	6.42	54.25	0.79	8.45	47.83	1.17	2589.58	7.00	5.25	47.50	0.80
513	4.50	45.50	0.82	10.11	41.00	1.22	2121.25	8.50	6.00	52.50	0.79	8.75	46.50	1.18	2562.50	7.00	5.00	45.25	0.80
514	3.50	54.00	0.88	15.43	50.50	1.31	2691.25	8.00	5.75	57.50	0.82	10.00	51.75	1.22	2801.25	6.75	5.25	47.38	0.80
515	4.75	45.75	0.81	9.63	41.00	1.21	2097.50	8.00	6.75	49.88	0.76	7.39	43.13	1.13	2275.00	7.00	5.75	42.50	0.76
516	4.00	51.50	0.86	12.88	47.50	1.27	2493.75	7.67	5.67	53.83	0.81	9.50	48.17	1.20	2598.33	6.83	5.00	45.08	0.80
517	4.50	49.50	0.83	11.00	45.00	1.24	2368.75	6.75	5.00	51.50	0.82	10.30	46.50	1.22	2491.25	6.50	5.00	46.50	0.81
518	4.13	48.25	0.84	11.70	44.13	1.25	2313.13	8.13	5.75	53.63	0.81	9.33	47.88	1.20	2619.38	6.75	5.25	42.75	0.78
519	5.25	44.88	0.79	8.55	39.63	1.17	2028.75	7.50	5.75	49.63	0.79	8.63	43.88	1.18	2360.00	6.38	5.50	42.38	0.77
520	6.25	39.38	0.73	6.30	33.13	1.08	1668.13	7.69	6.25	50.88	0.78	8.14	44.63	1.16	2367.81	6.75	5.88	43.06	0.76
521	3.50	56.00	0.88	16.00	52.50	1.31	2815.00	7.75	5.63	58.25	0.82	10.36	52.63	1.23	2833.13	7.00	4.88	48.63	0.82
522	3.50	54.75	0.88	15.64	51.25	1.31	2728.75	8.00	5.63	57.00	0.82	10.13	51.38	1.22	2794.38	7.00	5.25	47.38	0.80
523	4.25	57.00	0.86	13.41	52.75	1.28	2744.38	8.25	5.75	60.25	0.83	10.48	54.50	1.23	2962.50	6.25	5.25	47.75	0.80
524	4.50	56.75	0.85	12.61	52.25	1.27	2731.25	7.63	5.63	59.88	0.83	10.64	54.25	1.23	2902.50	6.38	5.88	47.88	0.78
525	4.25	51.25	0.85	12.06	47.00	1.26	2445.00	7.63	5.75	51.75	0.80	9.00	46.00	1.19	2478.13	7.00	5.25	44.00	0.79
526	3.50	54.25	0.88	15.50	50.75	1.31	2680.00	7.75	5.25	59.25	0.84	11.29	54.00	1.25	2937.50	7.00	4.75	47.75	0.82
527	3.50	53.75	0.88	15.36	50.25	1.31	2655.00	8.25	6.00	56.25	0.81	9.38	50.25	1.20	2726.25	6.50	4.75	47.25	0.82

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
528	3.75	53.63	0.87	14.30	49.88	1.29	2636.25	8.88	6.13	56.25	0.80	9.18	50.13	1.20	2767.50	6.50	5.13	45.38	0.80
529	4.63	45.25	0.81	9.78	40.63	1.21	2138.13	8.25	7.25	49.50	0.74	6.83	42.25	1.11	2207.50	7.00	5.75	44.00	0.77
530	3.75	54.75	0.87	14.60	51.00	1.30	2740.00	7.75	5.25	59.25	0.84	11.29	54.00	1.25	2937.50	7.00	5.00	49.25	0.82
531	4.08	56.08	0.86	13.73	52.00	1.29	2687.08	8.08	5.50	56.25	0.82	10.23	50.75	1.22	2782.92	6.83	5.17	48.17	0.81
532	3.50	55.25	0.88	15.79	51.75	1.31	2753.75	7.75	5.25	59.00	0.84	11.24	53.75	1.25	2925.00	7.00	5.00	49.25	0.82
533	3.75	54.75	0.87	14.60	51.00	1.30	2692.50	8.25	6.25	55.50	0.80	8.88	49.25	1.19	2652.50	6.50	5.25	44.25	0.79
534	5.58	44.17	0.78	7.91	38.58	1.15	1945.01	7.67	5.92	50.50	0.79	8.54	44.58	1.17	2395.42	6.67	6.50	42.00	0.73
535	5.15	48.65	0.81	9.45	43.50	1.20	2194.00	8.05	6.10	55.00	0.80	9.02	48.90	1.19	2630.25	6.90	6.40	43.45	0.74
536	3.50	53.75	0.88	15.36	50.25	1.31	2678.75	8.50	6.25	54.75	0.80	8.76	48.50	1.18	2638.75	7.00	5.25	45.50	0.79
537	4.50	53.00	0.84	11.78	48.50	1.25	2496.25	7.75	6.00	53.50	0.80	8.92	47.50	1.19	2541.25	6.50	5.25	45.25	0.79
538	3.88	52.69	0.86	13.60	48.81	1.28	2571.25	7.69	5.63	52.81	0.81	9.39	47.19	1.20	2555.31	7.06	5.50	45.13	0.78
539	3.75	50.50	0.86	13.47	46.75	1.28	2480.00	7.75	5.50	51.75	0.81	9.41	46.25	1.20	2526.25	7.00	5.25	45.75	0.79
540	4.00	47.00	0.84	11.75	43.00	1.25	2268.75	8.63	6.50	51.00	0.77	7.85	44.50	1.15	2426.88	6.75	5.25	42.38	0.78
541	3.75	55.25	0.87	14.73	51.50	1.30	2765.00	7.63	5.25	61.38	0.84	11.69	56.13	1.25	3031.88	7.13	4.88	49.25	0.82
542	3.75	56.00	0.87	14.93	52.25	1.30	2766.88	8.00	5.63	59.13	0.83	10.51	53.50	1.23	2900.63	6.75	4.88	48.25	0.82
543	4.50	51.00	0.84	11.33	46.50	1.25	2443.75	8.50	6.75	52.00	0.77	7.70	45.25	1.15	2428.75	7.00	5.75	43.75	0.77
544	3.75	49.75	0.86	13.27	46.00	1.28	2442.50	9.00	6.75	52.25	0.77	7.74	45.50	1.15	2488.75	7.00	5.25	43.25	0.78
545	3.50	53.17	0.88	15.19	49.67	1.30	2649.59	8.00	5.83	55.75	0.81	9.56	49.92	1.21	2701.67	6.83	5.17	44.83	0.79
546	3.75	50.50	0.86	13.47	46.75	1.28	2480.00	8.50	6.25	51.50	0.78	8.24	45.25	1.17	2476.25	7.00	5.00	48.00	0.81
547	3.75	54.75	0.87	14.60	51.00	1.30	2692.50	7.75	5.00	59.50	0.84	11.90	54.50	1.26	2986.25	7.25	5.00	49.50	0.82
571	6.75	39.25	0.71	5.81	32.50	1.05	1672.50	8.50	8.00	37.50	0.65	4.69	29.50	0.96	1522.50	7.00	5.75	46.00	0.78
20	9.44	19.81	0.35	2.10	10.38	0.52	352.50	9.38	10.44	23.13	0.38	2.22	12.69	0.56	533.44	6.31	5.94	33.75	0.70
21	9.63	20.13	0.35	2.09	10.50	0.52	311.25	8.63	9.56	21.81	0.39	2.28	12.25	0.58	523.44	6.25	5.81	33.25	0.70
22	10.42	21.42	0.35	2.06	11.00	0.51	332.29									6.33	5.58	34.71	0.72
23	10.13	20.75	0.34	2.05	10.63	0.51	341.25	9.63	11.13	23.50	0.36	2.11	12.38	0.53	476.25	6.38	6.00	34.06	0.70
24	9.83	20.50	0.35	2.08	10.67	0.52	335.42	9.33	10.58	23.25	0.37	2.20	12.67	0.55	514.58	6.42	6.08	33.83	0.70
25	8.92	18.75	0.36	2.10	9.83	0.52	361.04	8.92	9.67	20.88	0.37	2.16	11.21	0.54	489.17	6.33	5.88	30.79	0.68
26	9.81	20.50	0.35	2.09	10.69	0.52	338.44	8.81	10.38	23.00	0.38	2.22	12.63	0.56	482.81	6.19	5.81	34.69	0.71
27	9.94	21.63	0.37	2.18	11.69	0.55	364.69	8.88	10.75	23.75	0.38	2.21	13.00	0.56	471.88	6.31	6.25	34.69	0.69
28	10.50	21.08	0.34	2.01	10.58	0.49	252.08									6.50	6.75	31.25	0.64
29	10.36	21.29	0.35	2.06	10.93	0.51	305.53	9.64	11.11	24.25	0.37	2.18	13.14	0.55	518.03	6.43	5.79	35.25	0.72
30	9.90	20.85	0.36	2.11	10.95	0.53	357.50	9.55	10.75	23.20	0.37	2.16	12.45	0.54	508.50	6.25	5.80	35.25	0.72
31	10.25	21.60	0.36	2.11	11.35	0.53	349.00									6.35	5.95	35.05	0.71
32	10.35	22.00	0.36	2.13	11.65	0.53	378.25									6.33	5.53	36.28	0.74
33	10.04	21.17	0.36	2.11	11.13	0.53	322.71									6.50	6.46	33.00	0.67
34	10.53	20.56	0.32	1.95	10.03	0.48	279.72	10.17	11.75	22.83	0.32	1.94	11.08	0.47	403.75	7.64	8.11	28.81	0.56
35	10.75	20.90	0.32	1.94	10.15	0.47	279.50	10.70	12.40	23.35	0.31	1.88	10.95	0.45	386.00	7.70	8.50	28.20	0.54
36	11.35	20.75	0.29	1.83	9.40	0.43	232.50	10.05	12.10	23.15	0.31	1.91	11.05	0.46	357.75	7.60	8.15	29.05	0.56
37	10.50	20.33	0.32	1.94	9.83	0.47	277.92	10.00	12.13	23.08	0.31	1.90	10.96	0.46	346.04	7.75	8.25	28.04	0.55
38	11.13	21.42	0.32	1.93	10.29	0.47	249.37	10.00	12.13	23.58	0.32	1.95	11.46	0.47	371.04	7.58	8.25	29.00	0.56
39	11.00	20.42	0.30	1.86	9.42	0.44	233.33	10.08	12.08	22.75	0.31	1.88	10.67	0.45	343.33	7.63	8.46	28.50	0.54
40	10.54	20.17	0.31	1.91	9.63	0.46	303.13	10.83	11.75	22.67	0.32	1.93	10.92	0.47	458.75	8.04	8.17	28.04	0.55
41	11.00	20.81	0.31	1.89	9.81	0.46	276.88	10.00	11.75	22.88	0.32	1.95	11.13	0.48	390.00	7.38	7.44	29.50	0.60
42	12.20	23.60	0.32	1.93	11.40	0.47	318.25	10.60	12.85	25.65	0.33	2.00	12.80	0.49	426.25	7.60	8.10	31.70	0.59
43	11.00	20.42	0.30	1.86	9.42	0.44	257.08	11.00	12.25	22.58	0.30	1.84	10.33	0.44	397.92	8.17	8.58	28.83	0.54
98	10.54	19.83	0.31	1.88	9.29	0.45	231.04	9.63	11.50	20.75	0.29	1.80	9.25	0.42	284.38	7.75	8.79	25.00	0.48
99	10.88	18.67	0.26	1.72	7.79	0.39	128.33	10.08	12.00	20.50	0.26	1.71	8.50	0.39	242.92	8.13	8.71	25.17	0.49
100	11.25	19.50	0.27	1.73	8.25	0.40	198.75	10.19	11.81	20.75	0.27	1.76	8.94	0.41	292.50	8.19	8.19	28.19	0.55

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
101	11.00	19.56	0.28	1.78	8.56	0.41	214.38	10.00	11.94	21.31	0.28	1.79	9.38	0.42	284.69	8.00	8.25	28.25	0.55
102	11.00	20.10	0.29	1.83	9.10	0.43	193.75	10.30	11.65	22.60	0.32	1.94	10.95	0.47	419.25	8.10	8.05	29.05	0.57
103	10.00	18.88	0.31	1.89	8.88	0.45	241.88	9.63	11.44	20.88	0.29	1.83	9.44	0.43	299.69	7.50	7.88	26.06	0.54
104	11.00	19.50	0.28	1.77	8.50	0.41	163.75	9.50	11.75	21.50	0.29	1.83	9.75	0.43	273.75	7.75	8.50	25.75	0.50
105	10.50	20.00	0.31	1.90	9.50	0.46	261.25	9.75	11.63	21.50	0.30	1.85	9.88	0.44	315.63	7.88	8.50	25.25	0.50
106	11.75	21.00	0.28	1.79	9.25	0.42	177.50	10.75	13.00	23.00	0.28	1.77	10.00	0.41	286.25	8.00	8.88	26.50	0.50
185	10.00	21.00	0.35	2.10	11.00	0.52	360.00	10.00	10.00	24.25	0.42	2.43	14.25	0.62	712.50	6.25	5.88	33.00	0.70
186	10.00	22.50	0.38	2.25	12.50	0.57	450.83	9.58	10.17	27.00	0.45	2.66	16.83	0.67	786.25	6.25	5.75	34.42	0.71
187	9.25	22.25	0.41	2.41	13.00	0.61	523.33									5.75	4.83	35.75	0.76
188	9.50	21.75	0.39	2.29	12.25	0.58	470.00									6.25	5.50	33.88	0.72
189	9.50	21.25	0.38	2.24	11.75	0.56	445.00	9.75	10.50	24.50	0.40	2.33	14.00	0.59	628.75	6.25	5.75	35.00	0.72
190	9.33	20.75	0.38	2.22	11.42	0.56	475.83	10.00	9.67	24.00	0.43	2.48	14.33	0.63	748.33	7.00	6.25	32.50	0.68
191	9.67	23.58	0.42	2.44	13.92	0.62	537.50	9.08	9.17	27.17	0.50	2.96	18.00	0.73	892.09	6.08	5.17	37.08	0.76
192	9.50	22.75	0.41	2.39	13.25	0.61	496.25									6.00	5.00	35.25	0.75
193	9.42	22.00	0.40	2.34	12.58	0.59	486.67									5.92	5.42	35.50	0.74
194	9.67	20.67	0.36	2.14	11.00	0.54	439.17	9.83	10.08	24.17	0.41	2.40	14.08	0.61	680.42	6.67	6.08	32.42	0.68
195	9.83	21.08	0.36	2.14	11.25	0.54	443.75	10.17	10.25	25.00	0.42	2.44	14.75	0.62	729.58	6.75	6.75	33.00	0.66
196	9.25	22.25	0.41	2.41	13.00	0.61	495.63	8.75	9.00	26.13	0.49	2.90	17.13	0.72	832.50	6.00	4.63	36.38	0.77
197	9.38	22.00	0.40	2.35	12.63	0.59	453.13	8.75	8.63	25.63	0.50	2.97	17.00	0.73	861.88	6.13	4.88	36.00	0.76
237	9.88	20.75	0.36	2.10	10.88	0.52	365.63	10.44	11.19	24.63	0.38	2.20	13.44	0.56	600.63	6.50	5.88	35.25	0.71
238	9.42	19.50	0.35	2.07	10.08	0.51	322.08	8.83	9.75	21.25	0.37	2.18	11.50	0.55	487.92	6.25	5.75	33.33	0.71
239	10.92	21.58	0.33	1.98	10.67	0.48	208.75									6.50	6.83	31.17	0.64
240	10.33	21.08	0.34	2.04	10.75	0.51	276.25									6.67	6.58	32.42	0.66
241	8.50	18.00	0.36	2.12	9.50	0.53	380.00	8.00	8.00	16.75	0.35	2.09	8.75	0.52	437.50	6.50	6.25	27.25	0.63
242	9.75	21.00	0.37	2.15	11.25	0.54	372.50	9.00	10.00	22.25	0.38	2.23	12.25	0.56	517.50	6.50	6.00	32.50	0.69
243	9.94	20.75	0.35	2.09	10.81	0.52	350.63									6.50	5.75	35.19	0.72
244	9.75	20.50	0.36	2.10	10.75	0.52	335.63	9.50	10.75	23.25	0.37	2.16	12.50	0.54	506.25	6.75	6.38	33.00	0.68
245	10.00	20.75	0.35	2.08	10.75	0.52	355.42	9.50	10.92	23.42	0.36	2.15	12.50	0.54	490.42	6.50	6.00	34.00	0.70
246	9.25	19.00	0.35	2.05	9.75	0.51	321.25	6.88	7.25	16.75	0.40	2.31	9.50	0.58	439.38	6.38	6.00	32.00	0.68
247	11.00	22.00	0.33	2.00	11.00	0.49	288.75									6.50	6.38	32.88	0.68
248	10.50	20.25	0.32	1.93	9.75	0.47	297.50	10.50	11.88	23.00	0.32	1.94	11.13	0.47	425.63	8.25	7.88	28.00	0.56
249	10.50	19.75	0.31	1.88	9.25	0.45	320.00	10.50	11.75	22.25	0.31	1.89	10.50	0.46	406.25	7.75	8.75	28.00	0.52
250	10.75	20.75	0.32	1.93	10.00	0.47	262.50	9.75	11.00	21.00	0.31	1.91	10.00	0.46	381.25	7.50	7.50	29.25	0.59
251	10.50	20.25	0.32	1.93	9.75	0.47	327.19	10.63	11.75	22.63	0.32	1.93	10.88	0.47	436.88	7.88	8.19	27.81	0.55
252	10.75	20.25	0.31	1.88	9.50	0.45	308.75	10.50	11.88	22.19	0.30	1.87	10.31	0.45	385.00	8.31	8.19	27.06	0.54
253	10.33	19.92	0.32	1.93	9.58	0.47	305.00	10.00	11.08	21.75	0.32	1.96	10.67	0.48	430.42	7.42	7.17	30.83	0.62
254	10.63	20.75	0.32	1.95	10.13	0.48	351.88	10.13	11.75	23.00	0.32	1.96	11.25	0.48	408.13	7.38	7.00	29.75	0.62
255	10.75	20.63	0.31	1.92	9.88	0.46	303.75	10.00	11.88	22.63	0.31	1.91	10.75	0.46	359.38	7.50	8.00	28.50	0.56
256	10.56	20.25	0.31	1.92	9.69	0.46	306.25	10.50	11.88	22.38	0.31	1.88	10.50	0.45	394.38	7.94	8.31	27.56	0.54
257	10.38	20.63	0.33	1.99	10.25	0.49	334.38	10.50	11.88	23.25	0.32	1.96	11.38	0.48	438.13	7.38	7.25	31.13	0.62
258	10.75	21.50	0.33	2.00	10.75	0.49	335.63	11.00	12.25	24.25	0.33	1.98	12.00	0.49	481.25	7.75	7.25	29.75	0.61
259	10.13	18.88	0.30	1.86	8.75	0.44	205.94	9.38	10.81	20.44	0.31	1.89	9.63	0.45	344.69	7.69	8.44	24.19	0.48
260	9.75	19.63	0.34	2.01	9.88	0.50	303.75	9.25	10.38	21.63	0.35	2.08	11.25	0.52	455.63	7.13	6.88	28.25	0.61
261	10.75	20.75	0.32	1.93	10.00	0.47	333.75	9.50	11.75	23.25	0.33	1.98	11.50	0.49	361.25	7.50	8.25	29.25	0.56
262	10.58	20.75	0.32	1.96	10.17	0.48	318.33	10.50	11.75	23.50	0.33	2.00	11.75	0.49	468.75	7.75	8.00	28.50	0.56
263	10.50	20.63	0.33	1.96	10.13	0.48	292.50	10.00	11.50	22.25	0.32	1.93	10.75	0.47	395.00	8.13	8.00	29.00	0.57
264	10.50	19.75	0.31	1.88	9.25	0.45	248.75	10.08	11.33	21.92	0.32	1.93	10.58	0.47	410.42	7.50	7.83	28.67	0.57
265	10.00	20.25	0.34	2.03	10.25	0.50	346.25	9.75	11.25	21.75	0.32	1.93	10.50	0.47	382.50	7.50	7.50	28.00	0.58

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
266	11.50	21.75	0.31	1.89	10.25	0.46	203.75	10.50	12.25	23.50	0.31	1.92	11.25	0.47	396.25	8.00	8.50	29.00	0.55
267	11.00	20.75	0.31	1.89	9.75	0.45	297.50	10.50	11.00	22.50	0.34	2.05	11.50	0.51	527.50	7.75	7.25	29.25	0.60
268	10.50	19.75	0.31	1.88	9.25	0.45	248.75	10.50	11.75	21.75	0.30	1.85	10.00	0.44	381.25	8.00	7.50	26.50	0.56
269	10.50	20.75	0.33	1.98	10.25	0.48	298.75	10.50	11.75	22.25	0.31	1.89	10.50	0.46	406.25	7.75	8.75	28.00	0.52
270	9.75	19.75	0.34	2.03	10.00	0.50	310.00	9.00	10.50	21.50	0.34	2.05	11.00	0.51	407.50	7.50	7.25	28.50	0.59
360	10.75	19.13	0.28	1.78	8.38	0.41	181.25	10.00	11.75	20.63	0.27	1.76	8.88	0.40	277.50	8.13	8.75	24.75	0.48
361	10.88	19.00	0.27	1.75	8.13	0.40	180.63	10.00	12.00	20.13	0.25	1.68	8.13	0.37	216.25	8.13	8.75	25.25	0.49
362	10.50	19.92	0.31	1.90	9.42	0.46	288.75	9.75	11.75	21.00	0.28	1.79	9.25	0.42	272.50	7.67	8.58	25.58	0.50
363	10.50	19.75	0.31	1.88	9.25	0.45	248.75	10.13	11.75	21.00	0.28	1.79	9.25	0.42	308.13	8.00	8.50	25.13	0.49
364	11.00	19.88	0.29	1.81	8.88	0.42	158.75	10.00	11.69	21.50	0.30	1.84	9.81	0.44	330.31	7.75	8.56	26.00	0.50
365	11.25	19.92	0.28	1.77	8.67	0.41	219.58	10.00	11.83	21.58	0.29	1.82	9.75	0.43	313.33	8.00	8.17	28.75	0.56
366	11.25	19.75	0.27	1.76	8.50	0.40	211.25	10.25	12.38	21.25	0.26	1.72	8.88	0.39	241.88	8.00	8.63	27.38	0.52
367	10.63	20.13	0.31	1.89	9.50	0.46	273.13	10.06	11.69	22.00	0.31	1.88	10.31	0.45	361.25	7.69	8.19	28.13	0.55
368	11.19	19.88	0.28	1.78	8.69	0.41	214.69	10.00	11.44	21.81	0.31	1.91	10.38	0.46	382.19	7.88	7.94	28.25	0.56
369	11.50	20.88	0.29	1.82	9.38	0.43	213.44	10.56	12.50	22.31	0.28	1.79	9.81	0.42	306.56	8.13	9.19	25.63	0.47
370	10.92	19.75	0.29	1.81	8.83	0.43	188.33	10.00	11.75	21.92	0.30	1.87	10.17	0.45	342.08	7.83	8.67	28.75	0.54
371	11.00	20.00	0.29	1.82	9.00	0.43	260.00	10.00	11.50	21.75	0.31	1.89	10.25	0.46	370.00	8.00	8.50	28.00	0.53
372	10.58	19.75	0.30	1.87	9.17	0.45	268.33	10.00	11.50	21.42	0.30	1.86	9.92	0.45	353.33	7.75	8.42	27.42	0.53
373	12.67	23.83	0.31	1.88	11.17	0.45	265.41	10.50	12.58	23.83	0.31	1.89	11.25	0.46	364.58	7.92	9.25	29.42	0.52
374	11.19	20.06	0.28	1.79	8.88	0.42	218.13	10.13	12.00	21.81	0.29	1.82	9.81	0.43	312.50	7.88	8.31	28.44	0.55
375	11.00	19.75	0.28	1.80	8.75	0.42	176.25	10.50	12.25	21.00	0.26	1.71	8.75	0.39	271.25	8.50	9.00	25.25	0.47
376	10.92	18.92	0.27	1.73	8.00	0.40	170.42	9.83	11.83	20.58	0.27	1.74	8.75	0.40	247.50	8.17	8.75	25.33	0.49
377	10.55	19.85	0.31	1.88	9.30	0.45	275.00	10.35	11.50	21.75	0.31	1.89	10.25	0.46	403.25	7.75	8.25	27.25	0.54
378	11.00	24.88	0.39	2.26	13.88	0.57	456.25	10.63	12.50	22.38	0.28	1.79	9.88	0.42	315.63	8.00	8.50	28.25	0.54
379	11.50	20.92	0.29	1.82	9.42	0.43	221.46	10.38	12.33	22.67	0.30	1.84	10.33	0.44	330.63	8.13	8.67	26.33	0.50
380	9.88	20.69	0.35	2.09	10.81	0.52	350.63	9.63	11.00	22.50	0.34	2.05	11.50	0.51	444.38	7.44	8.25	28.25	0.55
381	11.50	20.25	0.28	1.76	8.75	0.41	200.00	10.50	13.00	22.25	0.26	1.71	9.25	0.39	225.00	8.50	9.38	26.25	0.47
382	13.00	24.75	0.31	1.90	11.75	0.46	350.00	11.25	14.25	25.75	0.29	1.81	11.50	0.43	290.00	8.75	10.75	28.50	0.45
491	10.50	20.92	0.33	1.99	10.42	0.49	220.00	6.83	8.67	17.83	0.35	2.06	9.17	0.51	284.16	6.00	6.83	31.67	0.65
492	10.50	19.75	0.31	1.88	9.25	0.45	248.75	9.50	11.25	21.25	0.31	1.89	10.00	0.45	333.75	7.50	8.50	25.50	0.50
494	11.50	20.88	0.29	1.82	9.38	0.43	160.00	10.13	12.75	22.25	0.27	1.75	9.50	0.40	225.63	8.25	9.13	25.63	0.47
495	10.79	19.43	0.29	1.80	8.64	0.42	228.57	10.29	12.46	21.00	0.26	1.68	8.54	0.38	219.82	7.82	8.57	25.61	0.50
496	10.63	19.25	0.29	1.81	8.63	0.43	158.13	9.75	11.50	21.00	0.29	1.83	9.50	0.43	308.75	7.88	8.50	25.75	0.50
497	10.00	18.75	0.30	1.88	8.75	0.45	223.75	9.50	11.50	20.75	0.29	1.80	9.25	0.42	272.50	7.75	8.25	25.50	0.51
548	9.00	22.00	0.42	2.44	13.00	0.62	507.50	8.88	9.00	25.25	0.47	2.81	16.25	0.70	800.63	5.88	4.63	35.75	0.77
549	9.50	22.00	0.40	2.32	12.50	0.59	553.75									6.00	5.75	37.00	0.73
550	9.75	22.13	0.39	2.27	12.38	0.57	440.63	9.13	9.25	25.63	0.47	2.77	16.38	0.69	806.88	6.25	5.75	35.38	0.72
551	9.75	21.75	0.38	2.23	12.00	0.56	481.25	9.25	9.13	24.25	0.45	2.66	15.13	0.67	768.13	6.00	5.13	35.50	0.75
552	9.50	20.50	0.37	2.16	11.00	0.54	407.50									6.25	5.25	32.75	0.72
553	10.00	22.50	0.38	2.25	12.50	0.57	482.50	9.25	9.50	27.75	0.49	2.92	18.25	0.73	888.75	6.25	5.75	36.25	0.73
554	8.50	23.00	0.46	2.71	14.50	0.68	677.50									5.75	5.00	36.75	0.76
555	9.50	20.50	0.37	2.16	11.00	0.54	407.50	10.00	10.00	22.75	0.39	2.28	12.75	0.58	637.50	6.38	6.13	32.50	0.68
556	9.50	22.42	0.40	2.36	12.92	0.60	471.67	9.00	9.25	26.83	0.49	2.90	17.58	0.72	855.41	6.08	5.17	36.25	0.75
557	9.25	22.25	0.41	2.41	13.00	0.61	436.25	8.75	9.00	26.00	0.49	2.89	17.00	0.72	826.25	5.75	4.75	38.25	0.78
558	10.00	22.00	0.38	2.20	12.00	0.55	386.25									6.25	5.75	35.00	0.72
559	9.25	22.42	0.42	2.42	13.17	0.61	571.25	9.83	10.17	25.00	0.42	2.46	14.83	0.62	710.00	6.17	4.92	35.83	0.76
560	9.50	24.25	0.44	2.55	14.75	0.65	595.00	9.00	9.50	26.50	0.47	2.79	17.00	0.70	802.50	6.00	5.75	35.50	0.72
561	9.25	25.13	0.46	2.72	15.88	0.68	710.63	9.50	10.00	27.25	0.46	2.73	17.25	0.69	815.00	6.13	5.75	35.50	0.72

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
562	9.79	21.17	0.37	2.16	11.38	0.54	398.54	9.58	9.75	24.58	0.43	2.52	14.83	0.64	725.83	6.21	5.92	35.17	0.71
563	9.25	24.75	0.46	2.68	15.50	0.67	695.83	9.17	8.92	25.42	0.48	2.85	16.50	0.71	848.75	6.08	5.42	35.67	0.74
564	8.50	31.00	0.57	3.65	22.50	0.84	1069.58	10.00	9.75	27.58	0.48	2.83	17.83	0.71	915.41	6.17	5.83	33.17	0.70
565	9.17	21.83	0.41	2.38	12.67	0.60	514.58	9.75	10.00	25.58	0.44	2.56	15.58	0.65	755.41	6.08	5.00	35.42	0.75
566	9.50	21.63	0.39	2.28	12.13	0.58	463.75	8.75	8.50	22.50	0.45	2.65	14.00	0.67	723.75	6.00	5.00	36.25	0.76
567	9.67	22.50	0.40	2.33	12.83	0.59	499.17									6.17	5.17	36.08	0.75
568	9.95	21.45	0.37	2.16	11.50	0.54	427.75	9.65	9.85	24.90	0.43	2.53	15.05	0.64	733.50	6.35	6.60	33.75	0.67
575	10.75	21.75	0.34	2.02	11.00	0.50	241.25	8.75	12.25	24.00	0.32	1.96	11.75	0.48	255.00	7.13	8.13	29.38	0.57
15	9.23	20.02	0.37	2.17	10.78	0.54	402.50	9.17	9.95	23.00	0.40	2.31	13.05	0.59	578.13	6.56	5.03	37.47	0.76
16	8.93	19.66	0.38	2.20	10.73	0.55	417.61	9.11	9.55	23.48	0.42	2.46	13.93	0.62	655.57	6.48	5.05	40.05	0.78
17	6.70	24.30	0.57	3.63	17.60	0.84	941.75	8.20	6.90	26.35	0.58	3.82	19.45	0.86	1096.00	6.10	4.25	42.35	0.82
18	9.38	19.88	0.36	2.12	10.50	0.53	370.63	9.25	10.13	22.63	0.38	2.23	12.50	0.56	541.88	6.56	5.13	37.19	0.76
19	9.25	19.00	0.35	2.05	9.75	0.51	345.00	9.42	10.00	22.50	0.38	2.25	12.50	0.57	569.58	6.33	5.25	37.17	0.75
226	9.13	19.00	0.35	2.08	9.88	0.52	339.38	9.50	9.63	22.75	0.41	2.36	13.13	0.60	644.38	6.50	5.00	39.50	0.78
227	8.75	20.08	0.39	2.30	11.33	0.58	447.92	9.17	9.25	23.42	0.43	2.53	14.17	0.64	700.42	6.50	5.00	39.17	0.77
228	9.00	20.25	0.38	2.25	11.25	0.57	420.00	8.75	9.63	23.75	0.42	2.47	14.13	0.63	623.13	6.38	5.00	39.75	0.78
229	9.25	18.00	0.32	1.95	8.75	0.47	283.13	9.38	11.75	21.13	0.29	1.80	9.38	0.42	243.13	7.75	8.88	23.50	0.45
230	8.75	20.50	0.40	2.34	11.75	0.59	492.50	9.50	9.50	24.00	0.43	2.53	14.50	0.64	725.00	6.75	5.00	38.88	0.77
231	10.00	20.00	0.33	2.00	10.00	0.49	286.25	9.75	10.75	23.00	0.36	2.14	12.25	0.54	517.50	7.50	6.25	33.00	0.68
232	9.75	19.88	0.34	2.04	10.13	0.50	328.13	9.50	10.13	23.19	0.39	2.29	13.06	0.58	593.75	6.69	5.19	39.06	0.77
233	9.83	19.17	0.32	1.95	9.33	0.47	260.84	9.42	10.33	22.67	0.37	2.19	12.33	0.55	529.59	6.50	5.42	36.33	0.74
234	9.50	19.25	0.34	2.03	9.75	0.50	321.25	9.25	10.00	23.00	0.39	2.30	13.00	0.58	578.75	6.88	5.00	40.00	0.78
235	9.50	20.50	0.37	2.16	11.00	0.54	360.00	9.25	10.25	22.50	0.37	2.20	12.25	0.55	517.50	6.50	5.25	36.75	0.75
236	10.00	20.25	0.34	2.03	10.25	0.50	298.75	9.75	11.38	23.13	0.34	2.03	11.75	0.50	433.13	8.13	7.75	28.38	0.57
572	10.38	17.00	0.24	1.64	6.63	0.36	141.25	10.00	11.75	20.75	0.28	1.77	9.00	0.41	283.75	7.75	9.00	21.38	0.41
573	10.00	17.25	0.27	1.73	7.25	0.39	204.17	9.75	11.00	20.50	0.30	1.86	9.50	0.45	356.25	7.25	6.58	30.67	0.65
574	9.50	19.88	0.35	2.09	10.38	0.52	376.25	8.75	9.50	23.13	0.42	2.43	13.63	0.62	610.00	6.50	5.13	37.13	0.76
1	3.75	38.45	0.82	10.25	34.70	1.22	1792.00									5.00	4.70	25.40	0.69
2	3.50	34.42	0.82	9.83	30.92	1.21	1605.21									4.63	4.58	23.04	0.67
3	3.75	39.06	0.82	10.42	35.31	1.22	1860.63									4.94	5.00	25.94	0.68
4	3.75	36.75	0.81	9.80	33.00	1.21	1673.75									4.75	5.00	24.25	0.66
5	5.58	34.42	0.72	6.16	28.83	1.07	1425.84									5.75	6.58	23.75	0.57
6	4.25	34.00	0.78	8.00	29.75	1.15	1495.42									4.58	5.00	23.00	0.64
7	3.75	36.83	0.82	9.82	33.08	1.21	1677.91									4.75	4.92	24.17	0.66
8	3.00	37.08	0.85	12.36	34.08	1.26	1743.75									4.50	4.75	25.75	0.69
9	3.19	37.25	0.84	11.69	34.06	1.25	1768.44	5.19	4.13	38.69	0.81	9.38	34.56	1.20	1829.06	4.69	4.75	23.94	0.67
10	3.00	37.31	0.85	12.44	34.31	1.26	1792.81	4.88	3.63	32.44	0.80	8.95	28.81	1.18	1559.38	4.75	4.75	23.56	0.66
11	3.38	35.63	0.83	10.56	32.25	1.22	1648.13	8.13	6.75	38.38	0.70	5.69	31.63	1.04	1711.88	5.00	5.25	24.00	0.64
12	3.75	39.50	0.83	10.53	35.75	1.23	1835.00									5.00	5.06	26.06	0.67
13	3.21	38.93	0.85	12.11	35.71	1.26	1873.93									5.21	5.04	24.39	0.66
14	3.38	37.50	0.83	11.11	34.13	1.24	1789.38	6.00	4.50	38.38	0.79	8.53	33.88	1.17	1836.25	5.00	5.00	23.50	0.65
44	3.60	35.30	0.81	9.81	31.70	1.21	1665.75	4.85	3.45	35.70	0.82	10.35	32.25	1.22	1745.50	4.10	3.55	28.65	0.78
45	3.25	43.25	0.86	13.31	40.00	1.28	2101.79	5.21	3.46	46.79	0.86	13.51	43.32	1.28	2332.32	4.46	3.32	35.04	0.83
46	3.39	39.61	0.84	11.67	36.21	1.25	1871.79	4.46	2.96	44.07	0.87	14.87	41.11	1.30	2197.86	3.61	2.57	35.54	0.87
47	2.80	40.20	0.87	14.36	37.40	1.29	1984.00									3.80	2.65	32.55	0.85
48	3.33	36.83	0.83	11.05	33.50	1.24	1738.33									3.83	3.08	30.75	0.82
49	3.58	39.08	0.83	10.91	35.50	1.23	1854.16									4.25	3.33	30.63	0.80
50	2.88	42.13	0.87	14.65	39.25	1.29	2069.38									4.06	2.75	32.19	0.84

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
51	3.25	38.00	0.84	11.69	34.75	1.25	1785.00	4.58	3.25	39.83	0.85	12.26	36.58	1.26	1955.83	4.00	3.58	28.75	0.78
52	3.50	38.75	0.83	11.07	35.25	1.24	1810.00									4.25	3.63	30.00	0.78
53	3.75	35.00	0.81	9.33	31.25	1.19	1657.50									4.25	3.50	32.63	0.81
54	3.75	36.25	0.81	9.67	32.50	1.20	1720.00									4.25	3.75	29.13	0.77
55	3.17	39.50	0.85	12.47	36.33	1.26	1872.08	4.75	3.58	39.58	0.83	11.05	36.00	1.24	1910.83	3.83	3.58	29.25	0.78
56	4.75	38.33	0.78	8.07	33.58	1.16	1655.41	5.25	5.33	38.92	0.76	7.30	33.58	1.13	1671.26	4.75	4.67	28.08	0.72
57	3.38	41.63	0.85	12.33	38.25	1.26	2007.50	5.00	3.13	45.25	0.87	14.48	42.13	1.29	2284.38	4.06	3.13	33.56	0.83
58	3.75	37.92	0.82	10.11	34.17	1.22	1771.67									3.75	3.00	31.17	0.82
59	3.25	39.31	0.85	12.10	36.06	1.26	1880.31									3.69	3.13	31.88	0.82
60	3.50	39.50	0.84	11.29	36.00	1.24	1847.50	4.63	3.25	39.38	0.85	12.12	36.13	1.26	1936.88	4.00	3.63	28.50	0.77
61	3.50	39.75	0.84	11.36	36.25	1.24	1852.08	4.75	3.75	39.50	0.83	10.53	35.75	1.23	1882.50	4.00	3.67	29.75	0.78
72	2.70	44.80	0.89	16.59	42.10	1.32	2209.50									4.15	3.55	26.50	0.76
73	3.56	39.94	0.84	11.21	36.38	1.24	1854.38									4.44	4.31	24.44	0.70
74	3.67	35.08	0.81	9.57	31.42	1.20	1642.08									4.25	3.92	27.25	0.75
75	2.75	33.83	0.85	12.30	31.08	1.26	1680.83	4.75	3.17	35.08	0.83	11.08	31.92	1.24	1746.24	4.25	3.83	25.08	0.73
76	3.75	33.50	0.80	8.93	29.75	1.18	1535.00	5.75	4.50	32.25	0.76	7.17	27.75	1.12	1506.25	4.50	4.25	24.25	0.70
77	2.50	45.25	0.90	18.10	42.75	1.33	2256.25	5.00	3.38	43.00	0.85	12.74	39.63	1.27	2135.63	4.25	3.88	26.50	0.74
78	2.75	34.63	0.85	12.59	31.88	1.26	1712.50	5.00	3.50	35.50	0.82	10.14	32.00	1.22	1742.50	4.38	4.13	24.13	0.71
79	3.15	34.75	0.83	11.03	31.60	1.23	1660.75	5.00	3.45	34.30	0.82	9.94	30.85	1.21	1689.75	4.50	4.05	24.10	0.71
80	3.25	33.69	0.82	10.37	30.44	1.22	1593.13	5.13	3.88	32.50	0.79	8.39	28.63	1.16	1550.00	4.69	4.44	22.94	0.68
81	2.50	35.63	0.87	14.25	33.13	1.29	1727.50	4.75	3.00	35.38	0.84	11.79	32.38	1.25	1785.00	4.25	3.88	24.50	0.73
82	2.50	37.75	0.88	15.10	35.25	1.30	1833.75	4.25	2.75	36.75	0.86	13.36	34.00	1.28	1842.50	4.00	3.25	26.75	0.78
83	2.42	38.33	0.88	15.86	35.92	1.31	1906.66	4.75	3.00	35.17	0.84	11.72	32.17	1.25	1774.59	4.00	3.50	25.67	0.76
84	2.38	37.13	0.88	15.63	34.75	1.30	1820.63	4.75	3.00	36.13	0.85	12.04	33.13	1.25	1822.50	4.00	3.00	26.13	0.79
85	3.00	34.42	0.84	11.47	31.42	1.24	1642.09	4.79	3.58	33.92	0.81	9.47	30.33	1.20	1631.46	4.25	4.04	23.29	0.70
86	2.75	38.92	0.87	14.15	36.17	1.29	1903.34	5.00	3.75	35.58	0.81	9.49	31.83	1.20	1710.41	4.42	4.00	24.92	0.72
87	2.38	38.88	0.88	16.37	36.50	1.31	1943.75	5.00	3.38	36.25	0.83	10.74	32.88	1.23	1798.13	4.50	3.75	26.00	0.75
88	2.25	37.92	0.89	16.85	35.67	1.32	1854.59	4.50	2.92	33.75	0.84	11.57	30.83	1.24	1692.08	3.75	3.42	24.92	0.76
89	3.50	32.75	0.81	9.36	29.25	1.19	1438.75	4.75	3.75	32.00	0.79	8.53	28.25	1.17	1507.50	4.00	4.00	23.50	0.71
90	2.50	34.50	0.86	13.80	32.00	1.28	1742.50	4.75	3.50	36.50	0.83	10.43	33.00	1.22	1768.75	4.25	3.50	24.50	0.75
91	3.63	35.56	0.81	9.81	31.94	1.21	1608.75	4.81	3.44	30.44	0.80	8.85	27.00	1.18	1480.63	4.75	5.25	23.81	0.64
92	3.75	40.33	0.83	10.76	36.58	1.23	1908.33									5.00	4.83	24.58	0.67
93	4.00	36.50	0.80	9.13	32.50	1.19	1601.25									5.00	6.25	26.00	0.61
94	3.00	37.00	0.85	12.33	34.00	1.26	1771.25	4.75	3.50	36.00	0.82	10.29	32.50	1.22	1743.75	4.75	5.00	24.75	0.66
95	3.00	39.00	0.86	13.00	36.00	1.27	1918.75									4.50	4.50	24.75	0.69
96	3.25	41.25	0.85	12.69	38.00	1.27	1971.25									5.00	5.00	24.38	0.66
97	4.50	33.75	0.76	7.50	29.25	1.13	1438.75									4.75	6.00	23.75	0.60
117	3.25	41.75	0.86	12.85	38.50	1.27	1984.38									4.25	4.75	26.25	0.69
118	3.50	40.75	0.84	11.64	37.25	1.25	1910.00	6.00	3.75	41.75	0.84	11.13	38.00	1.24	2113.75	4.50	4.50	26.50	0.71
119	3.50	41.13	0.84	11.75	37.63	1.25	1905.00	5.38	3.75	40.00	0.83	10.67	36.25	1.23	1966.88	5.88	6.38	25.75	0.60
121	3.50	41.75	0.85	11.93	38.25	1.25	1960.00									4.50	4.75	27.00	0.70
122	3.25	40.75	0.85	12.54	37.50	1.26	1946.25	5.00	3.25	37.00	0.84	11.38	33.75	1.24	1853.75	4.50	4.50	25.63	0.70
123	3.00	41.25	0.86	13.75	38.25	1.28	2007.50	4.25	3.00	40.25	0.86	13.42	37.25	1.28	1981.25	4.75	4.50	26.50	0.71
124	3.00	45.00	0.88	15.00	42.00	1.30	2195.00									4.50	4.25	26.75	0.73
125	5.25	33.00	0.73	6.29	27.75	1.07	1435.00	6.25	5.13	34.38	0.74	6.71	29.25	1.10	1569.38	4.25	3.88	26.38	0.74
126	5.00	35.42	0.75	7.08	30.42	1.12	1615.84									4.17	4.00	25.92	0.73
127	5.00	36.25	0.76	7.25	31.25	1.12	1657.50	6.25	5.00	37.00	0.76	7.40	32.00	1.13	1718.75	4.25	4.13	27.88	0.74
128	5.00	33.17	0.74	6.63	28.17	1.09	1479.59	6.08	5.00	35.08	0.75	7.02	30.08	1.11	1607.08	4.25	3.58	28.17	0.77

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
129	5.25	33.25	0.73	6.33	28.00	1.08	1471.25									4.25	3.63	28.13	0.77
130	4.75	34.06	0.76	7.17	29.31	1.12	1542.81									4.00	3.63	28.75	0.78
131	4.75	34.92	0.76	7.35	30.17	1.13	1611.25									4.25	4.00	26.42	0.74
132	5.25	31.50	0.71	6.00	26.25	1.06	1383.75	6.00	5.00	33.50	0.74	6.70	28.50	1.10	1520.00	4.25	4.00	28.50	0.75
133	5.30	33.60	0.73	6.34	28.30	1.08	1467.25	6.60	4.80	33.75	0.75	7.03	28.95	1.11	1618.50	4.25	4.05	27.35	0.74
134	4.88	36.19	0.76	7.42	31.31	1.13	1642.81	6.00	5.06	36.19	0.75	7.15	31.13	1.12	1645.31	4.19	4.06	27.38	0.74
135	5.33	37.33	0.75	7.00	32.00	1.11	1631.66	6.58	5.42	38.50	0.75	7.11	33.08	1.12	1765.00	4.50	4.50	27.83	0.72
136	5.33	32.92	0.72	6.17	27.58	1.07	1418.76	6.50	5.08	33.42	0.74	6.57	28.33	1.09	1551.26	4.25	4.25	26.25	0.72
137	4.50	33.63	0.76	7.47	29.13	1.13	1575.00	5.75	4.25	34.00	0.78	8.00	29.75	1.15	1630.00	4.00	3.75	27.75	0.76
138	5.50	33.13	0.72	6.02	27.63	1.06	1381.25	6.13	5.25	32.75	0.72	6.24	27.50	1.07	1458.13	4.25	4.38	26.38	0.72
139	4.38	37.13	0.79	8.49	32.75	1.17	1768.13	5.81	4.38	39.88	0.80	9.11	35.50	1.19	1911.56	4.00	3.31	34.38	0.82
140	4.75	33.00	0.75	6.95	28.25	1.11	1483.75	6.08	5.17	33.83	0.74	6.55	28.67	1.09	1520.41	4.50	3.83	26.50	0.75
141	5.10	35.25	0.75	6.91	30.15	1.11	1564.50	6.05	5.30	35.60	0.74	6.72	30.30	1.10	1586.25	4.40	4.15	28.15	0.74
142	5.08	31.00	0.72	6.10	25.92	1.06	1343.33									4.33	3.67	28.50	0.77
143	4.50	32.25	0.76	7.17	27.75	1.12	1506.25	6.00	4.75	33.25	0.75	7.00	28.50	1.11	1543.75	4.25	3.50	31.13	0.80
160	2.50	34.25	0.86	13.70	31.75	1.28	1706.25	4.00	2.75	34.00	0.85	12.36	31.25	1.26	1681.25	4.75	4.50	24.75	0.69
161	2.50	37.25	0.87	14.90	34.75	1.30	1856.25	5.00	3.50	37.75	0.83	10.79	34.25	1.23	1855.00	4.50	4.00	25.00	0.72
162	3.00	39.75	0.86	13.25	36.75	1.27	1908.75	5.00	3.25	40.63	0.85	12.50	37.38	1.26	2035.00	4.63	4.38	26.38	0.72
163	3.00	39.50	0.86	13.17	36.50	1.27	1896.25	4.83	3.17	39.25	0.85	12.39	36.08	1.26	1962.50	4.33	4.17	26.25	0.73
164	3.00	40.50	0.86	13.50	37.50	1.28	1970.00	4.75	3.00	38.50	0.86	12.83	35.50	1.27	1941.25	4.50	4.50	26.75	0.71
165	2.75	33.75	0.85	12.27	31.00	1.26	1645.00	4.63	3.13	34.75	0.83	11.12	31.63	1.24	1723.75	4.63	4.25	23.75	0.70
166	2.50	36.38	0.87	14.55	33.88	1.29	1812.50	4.63	3.50	36.75	0.83	10.50	33.25	1.22	1769.38	4.63	4.63	24.75	0.69
167	2.90	38.80	0.86	13.38	35.90	1.28	1880.50	4.90	3.65	38.10	0.83	10.44	34.45	1.22	1841.25	4.50	4.40	25.05	0.70
168	2.50	39.75	0.88	15.90	37.25	1.31	1957.50	5.00	3.00	39.25	0.86	13.08	36.25	1.27	2002.50	4.38	4.25	24.38	0.70
169	2.50	37.00	0.87	14.80	34.50	1.29	1796.25	4.88	2.88	39.00	0.86	13.57	36.13	1.28	1996.25	4.25	4.50	25.75	0.70
198	4.50	35.00	0.77	7.78	30.50	1.14	1596.25									4.75	5.00	24.00	0.66
200	4.25	33.50	0.77	7.88	29.25	1.15	1557.50									4.75	5.00	23.00	0.64
201	4.50	36.00	0.78	8.00	31.50	1.15	1527.50									5.50	6.88	24.63	0.56
202	4.50	35.00	0.77	7.78	30.50	1.14	1596.25									4.63	4.63	24.25	0.68
203	4.00	40.50	0.82	10.13	36.50	1.22	1896.25									4.75	4.50	27.25	0.72
205	3.75	36.75	0.81	9.80	33.00	1.21	1792.50									4.75	5.00	25.00	0.67
206	3.00	37.38	0.85	12.46	34.38	1.26	1825.63									4.38	4.50	25.75	0.70
207	3.75	38.25	0.82	10.20	34.50	1.22	1820.00									4.75	4.75	26.00	0.69
208	3.38	37.63	0.84	11.15	34.25	1.24	1795.63									4.88	4.75	25.00	0.68
209	3.38	41.25	0.85	12.22	37.88	1.26	1953.13									4.63	4.88	27.38	0.70
210	3.00	38.00	0.85	12.67	35.00	1.27	1845.00									4.75	4.75	25.38	0.68
211	3.75	38.75	0.82	10.33	35.00	1.22	1797.50									4.75	5.25	25.00	0.65
212	3.75	38.25	0.82	10.20	34.50	1.22	1772.50									5.25	5.00	24.50	0.66
213	3.58	36.33	0.82	10.14	32.75	1.22	1685.00									5.00	5.67	25.75	0.64
214	3.75	37.25	0.82	9.93	33.50	1.21	1746.25	6.00	3.75	40.00	0.83	10.67	36.25	1.23	2026.25	4.75	5.00	24.50	0.66
215	3.56	37.81	0.83	10.61	34.25	1.23	1777.81	5.19	4.06	38.06	0.81	9.37	34.00	1.20	1806.88	5.13	4.75	24.50	0.68
216	3.75	39.50	0.83	10.53	35.75	1.23	1835.00	5.50	4.50	41.00	0.80	9.11	36.50	1.19	1920.00	5.00	5.00	24.25	0.66
217	3.88	39.38	0.82	10.16	35.50	1.22	1858.13									4.63	5.00	24.88	0.67
218	3.25	38.92	0.85	11.97	35.67	1.25	1838.75	5.50	4.00	38.25	0.81	9.56	34.25	1.20	1855.00	4.67	4.83	24.75	0.67
219	3.50	36.00	0.82	10.29	32.50	1.22	1696.25									4.67	4.58	24.67	0.69
220	3.75	37.50	0.82	10.00	33.75	1.21	1711.25									4.75	5.00	25.13	0.67
271	3.75	36.88	0.82	9.83	33.13	1.21	1703.75									4.25	3.25	31.00	0.81
272	3.25	40.00	0.85	12.31	36.75	1.26	1932.50									3.50	3.00	30.75	0.82

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
273	3.42	36.75	0.83	10.76	33.33	1.23	1730.00	4.25	3.00	40.92	0.86	13.64	37.92	1.28	2014.59	4.00	2.67	35.42	0.86
274	3.25	39.50	0.85	12.15	36.25	1.26	1860.00	4.75	2.92	41.08	0.87	14.09	38.17	1.29	2082.49	3.50	2.50	34.33	0.86
275	3.81	38.69	0.82	10.15	34.88	1.22	1785.31	5.13	4.19	42.13	0.82	10.06	37.94	1.22	1985.94	5.19	4.69	37.69	0.78
276	3.38	41.00	0.85	12.15	37.63	1.26	1934.69	5.00	3.13	43.75	0.87	14.00	40.63	1.29	2209.38	4.06	2.75	30.81	0.84
277	3.75	38.08	0.82	10.16	34.33	1.22	1811.66									4.25	3.50	30.08	0.79
278	3.75	37.13	0.82	9.90	33.38	1.21	1751.88	5.19	3.38	38.75	0.84	11.48	35.38	1.24	1940.94	4.25	3.56	28.81	0.78
279	3.38	38.00	0.84	11.26	34.63	1.24	1790.63	4.75	3.38	39.50	0.84	11.70	36.13	1.25	1936.88	4.13	3.88	29.25	0.77
280	3.00	38.38	0.85	12.79	35.38	1.27	1851.88	4.50	3.50	39.25	0.84	11.21	35.75	1.24	1882.50	4.00	3.50	30.00	0.79
281	3.42	36.50	0.83	10.68	33.08	1.23	1725.42									4.33	3.67	29.92	0.78
282	3.50	38.50	0.83	11.00	35.00	1.24	1815.31									3.69	3.00	31.69	0.83
283	3.00	38.75	0.86	12.92	35.75	1.27	1882.50	4.50	3.25	40.75	0.85	12.54	37.50	1.26	1993.75	4.00	3.75	28.50	0.77
284	3.00	39.42	0.86	13.14	36.42	1.27	1907.92									4.00	2.75	32.17	0.84
285	3.25	40.13	0.85	12.35	36.88	1.26	1915.00									3.38	3.00	30.50	0.82
286	3.00	39.92	0.86	13.31	36.92	1.28	1925.00									4.00	2.75	31.50	0.84
287	3.75	38.63	0.82	10.30	34.88	1.22	1791.25	5.00	3.75	37.88	0.82	10.10	34.13	1.22	1825.00	4.25	3.50	29.38	0.79
288	3.10	43.40	0.87	14.00	40.30	1.29	2124.25	5.00	3.25	45.50	0.87	14.00	42.25	1.29	2278.75	3.95	3.05	33.55	0.83
289	4.50	40.25	0.80	8.94	35.75	1.19	1811.25	5.75	5.25	42.00	0.78	8.00	36.75	1.15	1885.00	5.00	5.00	28.50	0.70
290	3.75	36.50	0.81	9.73	32.75	1.21	1685.00	4.25	3.75	40.25	0.83	10.73	36.50	1.23	1872.50	4.25	2.75	29.00	0.83
291	3.50	37.75	0.83	10.79	34.25	1.23	1783.75									4.25	3.25	31.38	0.81
292	3.00	41.25	0.86	13.75	38.25	1.28	2031.25	5.50	3.75	45.75	0.85	12.20	42.00	1.26	2266.25	4.25	2.75	33.75	0.85
293	3.25	40.50	0.85	12.46	37.25	1.26	1921.88									3.75	3.13	29.13	0.81
294	3.25	39.38	0.85	12.12	36.13	1.26	1865.63	4.75	3.50	40.00	0.84	11.43	36.50	1.24	1943.75	4.00	3.63	29.25	0.78
295	3.75	37.25	0.82	9.93	33.50	1.21	1722.50	5.00	3.75	38.50	0.82	10.27	34.75	1.22	1856.25	4.25	3.75	29.00	0.77
296	3.25	39.00	0.85	12.00	35.75	1.25	1882.50	4.25	2.75	45.50	0.89	16.55	42.75	1.32	2280.00	4.25	2.75	35.00	0.85
297	3.75	37.25	0.82	9.93	33.50	1.21	1746.25	5.00	3.75	38.38	0.82	10.23	34.63	1.22	1850.00	4.25	3.63	29.63	0.78
298	3.75	35.50	0.81	9.47	31.75	1.20	1635.00	5.25	4.00	37.75	0.81	9.44	33.75	1.20	1806.25	4.25	3.50	29.50	0.79
299	3.25	41.00	0.85	12.62	37.75	1.27	1982.50	5.00	3.00	44.50	0.87	14.83	41.50	1.30	2265.00	4.25	2.67	33.17	0.85
317	2.63	44.31	0.89	16.88	41.69	1.32	2203.13									4.13	3.75	27.13	0.76
318	3.08	42.00	0.86	13.62	38.92	1.28	2032.92									4.25	4.25	25.50	0.71
319	2.50	44.69	0.89	17.88	42.19	1.33	2257.81	5.00	3.00	43.00	0.87	14.33	40.00	1.29	2190.00	4.44	3.38	29.00	0.79
320	2.63	37.63	0.87	14.33	35.00	1.29	1845.00	5.00	3.75	34.75	0.81	9.27	31.00	1.19	1668.75	4.50	4.00	26.13	0.73
321	3.25	33.56	0.82	10.33	30.31	1.22	1604.69	5.25	3.94	32.94	0.79	8.37	29.00	1.16	1574.69	4.56	4.19	24.44	0.71
322	2.67	34.08	0.85	12.78	31.42	1.27	1673.74	4.75	3.00	34.58	0.84	11.53	31.58	1.24	1745.41	4.25	4.00	27.42	0.75
323	2.88	35.75	0.85	12.43	32.88	1.26	1679.38	4.75	3.75	34.75	0.81	9.27	31.00	1.19	1645.00	4.25	4.00	25.13	0.73
324	2.63	34.81	0.86	13.26	32.19	1.27	1704.38	5.00	3.19	35.06	0.83	11.00	31.88	1.23	1765.94	4.25	3.81	24.75	0.73
325	2.50	35.13	0.87	14.05	32.63	1.28	1773.75	4.50	3.25	34.75	0.83	10.69	31.50	1.23	1693.75	4.38	3.88	24.75	0.73
326	2.50	36.42	0.87	14.57	33.92	1.29	1782.92	4.17	3.58	36.08	0.82	10.07	32.50	1.21	1680.41	4.00	3.75	25.42	0.74
327	2.54	37.00	0.87	14.56	34.46	1.29	1849.58	5.08	3.33	37.50	0.84	11.25	34.17	1.24	1874.58	4.08	3.71	25.58	0.75
328	2.42	36.83	0.88	15.24	34.42	1.30	1815.83	4.42	2.83	37.33	0.86	13.18	34.50	1.27	1875.41	4.00	3.42	25.92	0.77
329	2.44	40.44	0.89	16.59	38.00	1.31	1989.06	4.81	2.81	41.13	0.87	14.62	38.31	1.29	2105.63	4.00	3.38	28.00	0.78
330	2.63	35.33	0.86	13.46	32.71	1.28	1746.25	4.92	3.54	34.00	0.81	9.60	30.46	1.20	1653.54	4.42	3.71	25.25	0.74
331	2.69	34.00	0.85	12.65	31.31	1.26	1672.50	4.25	3.50	34.75	0.82	9.93	31.25	1.21	1633.75	4.06	3.94	24.75	0.73
332	2.75	32.50	0.84	11.82	29.75	1.25	1594.38	4.25	3.50	31.25	0.80	8.93	27.75	1.18	1458.75	4.25	4.00	22.50	0.70
333	3.00	33.50	0.84	11.17	30.50	1.24	1596.25	4.75	3.75	31.00	0.78	8.27	27.25	1.16	1457.50	4.25	3.88	22.38	0.70
334	3.88	33.88	0.79	8.74	30.00	1.18	1464.38	4.88	4.50	32.75	0.76	7.28	28.25	1.12	1448.13	4.25	4.75	24.75	0.68
335	2.50	38.00	0.88	15.20	35.50	1.30	1846.25	4.50	2.50	34.75	0.87	13.90	32.25	1.28	1802.50	3.50	3.50	26.25	0.76
336	2.40	37.95	0.88	15.81	35.55	1.31	1858.25	4.30	3.10	36.95	0.85	11.92	33.85	1.25	1806.50	3.70	3.45	26.60	0.77
337	3.00	34.50	0.84	11.50	31.50	1.24	1646.25	4.75	3.75	33.75	0.80	9.00	30.00	1.18	1595.00	4.50	3.75	27.75	0.76

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
338	2.75	42.75	0.88	15.55	40.00	1.30	2134.58	5.00	3.08	40.58	0.86	13.16	37.50	1.27	2057.08	4.25	3.75	28.25	0.77
339	3.25	30.25	0.81	9.31	27.00	1.19	1421.25	5.13	3.88	30.00	0.77	7.74	26.13	1.14	1425.00	4.50	4.13	24.13	0.71
340	3.25	38.50	0.84	11.85	35.25	1.25	1833.75	5.00	3.75	38.75	0.82	10.33	35.00	1.22	1868.75	4.50	4.25	26.25	0.72
341	2.50	35.25	0.87	14.10	32.75	1.28	1780.00	4.75	3.50	34.50	0.82	9.86	31.00	1.21	1668.75	4.50	4.00	25.00	0.72
342	3.00	36.00	0.85	12.00	33.00	1.25	1721.25	5.25	3.00	35.25	0.84	11.75	32.25	1.25	1826.25	4.25	5.00	24.25	0.66
343	3.00	37.58	0.85	12.53	34.58	1.26	1832.08	4.92	3.50	37.08	0.83	10.60	33.58	1.23	1813.75	5.00	5.08	23.08	0.64
344	3.00	37.00	0.85	12.33	34.00	1.26	1771.25	4.75	3.00	33.25	0.83	11.08	30.25	1.23	1678.75	4.75	5.00	23.75	0.65
345	3.75	38.50	0.82	10.27	34.75	1.22	1785.00									4.50	4.50	25.00	0.69
346	3.75	38.00	0.82	10.13	34.25	1.22	1760.00									5.00	4.88	24.06	0.66
347	6.25	20.25	0.53	3.24	14.00	0.78	605.00	6.25	6.50	24.00	0.57	3.69	17.50	0.85	851.25	6.50	7.50	19.00	0.43
348	3.38	39.56	0.84	11.72	36.19	1.25	1845.00	4.63	3.00	34.81	0.84	11.60	31.81	1.25	1745.00	4.69	5.13	24.00	0.65
349	4.83	34.50	0.75	7.14	29.67	1.12	1443.75									6.42	8.00	26.58	0.54
350	3.75	39.00	0.82	10.40	35.25	1.22	1810.00									4.50	4.50	25.50	0.70
351	3.00	37.25	0.85	12.42	34.25	1.26	1783.75	4.75	3.50	36.75	0.83	10.50	33.25	1.22	1781.25	5.00	4.75	23.25	0.66
352	3.00	37.25	0.85	12.42	34.25	1.26	1831.25	4.75	3.50	36.25	0.82	10.36	32.75	1.22	1756.25	5.00	4.75	23.75	0.67
353	4.00	36.50	0.80	9.13	32.50	1.19	1648.75									5.50	6.25	25.75	0.61
354	4.50	35.50	0.78	7.89	31.00	1.15	1478.75	4.25	3.50	29.75	0.79	8.50	26.25	1.17	1383.75	5.75	6.75	25.25	0.58
355	4.38	37.50	0.79	8.57	33.13	1.17	1668.13									5.25	5.75	24.88	0.62
357	3.25	39.33	0.85	12.10	36.08	1.26	1875.41	4.92	3.58	40.92	0.84	11.42	37.33	1.24	1993.34	4.58	4.42	24.75	0.70
358	3.38	38.50	0.84	11.41	35.13	1.24	1839.38									5.63	5.63	25.75	0.64
359	3.75	37.50	0.82	10.00	33.75	1.21	1711.25	5.00	4.00	39.75	0.82	9.94	35.75	1.21	1882.50	4.75	5.25	24.50	0.65
383	3.50	40.00	0.84	11.43	36.50	1.24	1872.50	5.00	4.25	40.25	0.81	9.47	36.00	1.20	1871.25	5.50	6.50	26.00	0.60
384	3.50	40.75	0.84	11.64	37.25	1.25	1910.00	5.00	3.50	36.75	0.83	10.50	33.25	1.22	1805.00	5.00	4.75	25.75	0.69
385	3.50	40.25	0.84	11.50	36.75	1.25	1885.00									4.75	4.50	26.00	0.70
386	3.25	44.00	0.86	13.54	40.75	1.28	2108.75									4.75	4.75	26.50	0.70
387	3.00	41.25	0.86	13.75	38.25	1.28	1983.75	4.75	3.00	39.75	0.86	13.25	36.75	1.27	2003.75	4.25	4.75	26.00	0.69
388	3.50	43.00	0.85	12.29	39.50	1.26	1998.75	4.25	3.00	39.00	0.86	13.00	36.00	1.27	1918.75	4.75	4.75	29.75	0.72
389	3.50	40.00	0.84	11.43	36.50	1.24	1872.50									4.38	4.75	26.13	0.69
390	3.50	40.75	0.84	11.64	37.25	1.25	1910.00	5.50	3.75	41.50	0.83	11.07	37.75	1.24	2053.75	4.50	5.00	26.00	0.68
391	3.33	42.08	0.85	12.63	38.75	1.27	2000.83	4.75	3.25	37.17	0.84	11.44	33.92	1.24	1838.34	4.58	4.83	26.58	0.69
392	3.00	41.25	0.86	13.75	38.25	1.28	1983.75	4.25	3.00	36.75	0.85	12.25	33.75	1.26	1806.25	4.75	4.50	25.75	0.70
393	3.00	40.25	0.86	13.42	37.25	1.28	1957.50	5.00	3.50	43.00	0.85	12.29	39.50	1.26	2117.50	4.50	4.50	26.75	0.71
394	3.25	41.13	0.85	12.65	37.88	1.27	1965.00	4.88	3.50	37.63	0.83	10.75	34.13	1.23	1836.88	4.63	4.50	26.00	0.70
395	3.00	47.50	0.88	15.83	44.50	1.31	2320.00	4.75	3.50	34.25	0.81	9.79	30.75	1.21	1656.25	4.50	4.00	31.00	0.77
397	3.00	45.75	0.88	15.25	42.75	1.30	2208.75	4.75	3.50	43.50	0.85	12.43	40.00	1.26	2118.75	4.25	4.00	28.50	0.75
398	3.00	43.00	0.87	14.33	40.00	1.29	2095.00	4.75	3.50	35.50	0.82	10.14	32.00	1.22	1718.75	4.50	4.75	26.75	0.70
399	3.17	41.67	0.86	13.16	38.50	1.27	1996.25	4.42	3.50	38.92	0.83	11.12	35.42	1.24	1857.92	4.75	5.08	27.67	0.69
400	4.25	41.50	0.81	9.76	37.25	1.21	1838.75	5.00	4.63	40.13	0.79	8.68	35.50	1.18	1810.63	6.00	7.00	26.50	0.58
401	4.50	37.00	0.78	8.22	32.50	1.16	1743.75									4.38	3.75	25.75	0.75
402	5.06	39.75	0.77	7.85	34.69	1.15	1811.56									4.13	3.81	29.25	0.77
403	4.75	32.25	0.74	6.79	27.50	1.10	1493.75	6.00	4.83	34.00	0.75	7.03	29.17	1.11	1569.17	4.25	3.83	27.75	0.76
404	4.50	36.00	0.78	8.00	31.50	1.15	1658.13									4.25	3.50	30.13	0.79
405	5.00	34.19	0.74	6.84	29.19	1.10	1554.38	6.25	4.88	34.13	0.75	7.00	29.25	1.11	1593.13	4.25	4.13	26.88	0.73
406	5.25	33.75	0.73	6.43	28.50	1.08	1448.75	6.25	4.75	35.00	0.76	7.37	30.25	1.13	1655.00	4.25	3.75	29.63	0.78
407	5.33	36.33	0.74	6.81	31.00	1.10	1589.58	6.17	5.42	36.58	0.74	6.75	31.17	1.10	1629.58	4.08	4.25	26.08	0.72
408	4.33	36.42	0.79	8.40	32.08	1.17	1691.26	6.17	4.83	38.50	0.78	7.97	33.67	1.15	1810.00	4.08	3.50	31.17	0.80
409	5.25	32.00	0.72	6.10	26.75	1.06	1408.75	6.13	4.50	35.75	0.78	7.94	31.25	1.15	1716.88	4.00	3.63	31.13	0.79
410	4.25	38.88	0.80	9.15	34.63	1.19	1873.75	5.50	4.00	42.25	0.83	10.56	38.25	1.23	2055.00	4.00	4.00	35.00	0.79

Appendix I: Yield Map and Satellite Parameter Database

AOI ID	240-2	240-3	240NDVI	240 RVI	240 DVI	240 SAVI	240 TVI	251-1	251-2	251-3	251NDVI	251 RVI	251 DVI	251 SAVI	251 TVI	287-1	287-2	287-3	287NDVI
411	4.50	37.00	0.78	8.22	32.50	1.16	1743.75									4.25	3.50	29.00	0.78
412	4.50	38.25	0.79	8.50	33.75	1.17	1818.13									4.25	4.00	27.25	0.74
413	5.58	36.33	0.73	6.51	30.75	1.09	1577.08									4.50	4.58	28.00	0.72
414	5.00	35.50	0.75	7.10	30.50	1.12	1620.00	6.00	4.38	37.88	0.79	8.66	33.50	1.18	1829.38	4.25	4.00	27.63	0.75
415	4.50	34.25	0.77	7.61	29.75	1.14	1618.13	6.63	5.13	34.75	0.74	6.78	29.63	1.10	1623.75	4.25	3.75	25.88	0.75
416	5.88	35.19	0.71	5.99	29.31	1.06	1453.75									4.63	4.75	27.69	0.71
417	6.25	36.42	0.71	5.83	30.17	1.05	1468.75									5.25	5.42	28.58	0.68
418	5.00	35.08	0.75	7.02	30.08	1.11	1583.33									4.25	3.75	25.58	0.74
419	5.00	35.25	0.75	7.05	30.25	1.11	1595.63	6.25	5.13	35.50	0.75	6.93	30.38	1.11	1625.63	4.13	4.00	26.00	0.73
420	4.83	35.25	0.76	7.29	30.42	1.12	1623.75	6.00	4.42	37.08	0.79	8.40	32.67	1.17	1783.74	4.00	3.42	29.50	0.79
421	4.88	30.50	0.72	6.26	25.63	1.07	1376.25	6.00	4.50	32.25	0.76	7.17	27.75	1.12	1530.00	4.00	3.75	28.00	0.76
423	4.69	32.25	0.75	6.88	27.56	1.10	1490.94									4.31	3.50	27.69	0.78
424	5.45	29.10	0.68	5.34	23.65	1.01	1211.00									4.20	3.45	29.50	0.79
425	4.25	36.25	0.79	8.53	32.00	1.17	1710.83									4.25	3.50	27.50	0.77
426	4.42	37.67	0.79	8.53	33.25	1.17	1789.17	6.00	4.50	38.08	0.79	8.46	33.58	1.17	1821.66	4.00	3.67	31.83	0.79
427	5.67	36.67	0.73	6.47	31.00	1.09	1565.84	6.25	5.42	36.67	0.74	6.77	31.25	1.10	1641.67	4.42	4.58	30.25	0.74
428	5.25	31.25	0.71	5.95	26.00	1.05	1359.38	6.25	4.50	33.13	0.76	7.36	28.63	1.13	1597.50	4.13	3.75	27.75	0.76
429	4.50	34.08	0.77	7.57	29.58	1.14	1597.91									4.17	3.50	29.67	0.79
430	5.25	34.00	0.73	6.48	28.75	1.08	1508.75	6.25	4.50	35.75	0.78	7.94	31.25	1.15	1728.75	4.50	4.00	27.75	0.75
431	5.13	32.63	0.73	6.37	27.50	1.08	1481.88	6.25	5.25	33.50	0.73	6.38	28.25	1.08	1507.50	4.31	4.19	26.19	0.72
432	4.83	36.50	0.77	7.55	31.67	1.14	1646.67	6.50	4.83	36.83	0.77	7.62	32.00	1.14	1758.33	4.25	4.00	27.75	0.75
433	5.75	36.00	0.72	6.26	30.25	1.07	1500.63	6.63	6.00	35.63	0.71	5.94	29.63	1.05	1540.63	4.38	5.00	27.50	0.69
446	3.00	39.50	0.86	13.17	36.50	1.27	1896.25	5.00	3.00	39.75	0.86	13.25	36.75	1.27	2027.50	4.25	4.00	26.50	0.74
447	3.00	35.50	0.84	11.83	32.50	1.25	1696.25	4.50	3.50	35.75	0.82	10.21	32.25	1.22	1707.50	4.50	4.75	24.00	0.67
448	2.67	40.17	0.88	15.06	37.50	1.30	1977.92	4.75	3.17	39.75	0.85	12.55	36.58	1.26	1979.58	4.25	4.17	26.25	0.73
449	3.00	36.00	0.85	12.00	33.00	1.25	1721.25	5.00	3.50	38.25	0.83	10.93	34.75	1.23	1880.00	4.50	4.50	24.75	0.69
450	3.00	36.88	0.85	12.29	33.88	1.26	1776.88	4.75	4.00	37.25	0.81	9.31	33.25	1.19	1733.75	4.63	4.50	24.50	0.69
451	3.00	38.25	0.85	12.75	35.25	1.27	1845.63	4.50	3.75	35.63	0.81	9.50	31.88	1.20	1665.00	4.38	4.25	24.00	0.70
452	2.50	40.75	0.88	16.30	38.25	1.31	2043.13	4.75	2.75	39.13	0.87	14.23	36.38	1.29	2008.75	4.25	4.00	26.25	0.74
453	2.38	37.13	0.88	15.63	34.75	1.30	1880.00	4.75	3.00	39.25	0.86	13.08	36.25	1.27	1978.75	4.25	4.25	26.00	0.72
454	3.00	39.08	0.86	13.03	36.08	1.27	1875.41	4.25	2.83	35.92	0.85	12.68	33.08	1.26	1788.76	4.58	4.58	26.33	0.70
455	3.75	34.25	0.80	9.13	30.50	1.19	1620.00	4.50	2.75	36.75	0.86	13.36	34.00	1.28	1866.25	4.75	4.75	28.50	0.71
456	2.50	37.25	0.87	14.90	34.75	1.30	1785.00	4.50	2.75	35.25	0.86	12.82	32.50	1.27	1791.25	4.25	4.25	25.50	0.71
457	3.00	34.25	0.84	11.42	31.25	1.24	1562.50	4.50	2.75	33.25	0.85	12.09	30.50	1.25	1691.25	4.50	4.25	23.75	0.70
594	3.50	35.42	0.82	10.12	31.92	1.21	1667.09									4.50	4.42	26.25	0.71
595	3.50	38.17	0.83	10.90	34.67	1.23	1765.00									4.75	5.75	25.75	0.63

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
62	10.48	45.50	1.23	2422.25	10.10	12.50	33.40	0.46	2.67	20.90	0.68	817.00	40.95	38.55	261.10	4.24	49.93
63	7.95	39.08	1.15	2084.79	9.38	10.50	30.25	0.48	2.88	19.75	0.72	880.63	44.88	47.67	191.21	3.39	25.98
64	9.50	42.50	1.20	2264.11	10.46	13.43	32.11	0.41	2.39	18.68	0.61	652.33	41.93	40.04	241.39	4.09	44.43
65	8.82	40.06	1.18	2115.94	10.38	12.56	31.25	0.43	2.49	18.69	0.63	726.56	41.88	40.19	244.13	4.08	43.49
66	8.30	38.30	1.17	2052.75	9.70	10.70	34.70	0.53	3.24	24.00	0.78	1105.00	43.75	46.50	185.45	3.41	25.79
67	9.23	41.95	1.20	2249.50	10.50	12.95	33.10	0.44	2.56	20.15	0.65	774.75	42.10	39.95	242.50	4.10	44.13
68	9.45	43.31	1.20	2296.25	10.13	12.56	32.88	0.45	2.62	20.31	0.66	784.06	41.63	40.50	258.75	4.18	45.27
69	9.53	42.63	1.20	2273.75	10.50	13.25	32.13	0.42	2.42	18.88	0.62	682.50	42.00	40.44	247.19	4.09	45.18
70	8.68	38.88	1.18	2068.44	10.19	13.00	28.50	0.37	2.19	15.50	0.55	507.81	41.44	40.06	241.25	4.04	44.19
71	9.65	42.54	1.21	2273.54	10.46	12.63	34.00	0.46	2.69	21.38	0.68	862.92	41.87	40.29	238.08	4.06	42.67
107	9.55	42.75	1.20	2327.50	11.25	13.75	29.25	0.36	2.13	15.50	0.53	537.50	44.25	42.75	237.25	3.95	42.51
108	7.96	39.13	1.15	2069.06	10.56	13.69	26.06	0.31	1.90	12.38	0.46	321.88					
109	8.88	42.38	1.19	2249.38	10.75	14.38	29.25	0.34	2.03	14.88	0.51	399.38	42.38	42.88	250.75	3.98	42.98
110	9.75	43.75	1.21	2401.25	11.13	14.75	31.25	0.36	2.12	16.50	0.53	480.63	44.88	41.25	261.13	4.15	48.69
111	9.80	44.00	1.21	2366.25	11.00	15.00	29.00	0.32	1.93	14.00	0.47	320.00	43.63	41.13	257.00	4.11	48.44
112	8.59	38.88	1.18	2074.38	10.88	13.75	26.50	0.32	1.93	12.75	0.47	364.38	43.88	40.88	250.63	4.09	45.84
113	8.90	39.50	1.19	2165.00	11.25	14.00	27.50	0.33	1.96	13.50	0.48	413.75	44.75	44.75	233.25	3.81	40.77
114	8.54	38.63	1.17	2085.63	10.75	13.13	30.38	0.40	2.31	17.25	0.59	636.88	43.50	43.50	237.13	3.90	41.21
115	8.93	41.63	1.19	2247.50	10.75	13.75	31.50	0.39	2.29	17.75	0.58	602.50					
144	7.17	35.50	1.12	1893.75	10.50	13.75	27.00	0.33	1.96	13.25	0.48	353.75	44.00	41.25	237.25	3.99	44.25
145	8.32	37.50	1.17	2029.38	10.50	13.88	26.75	0.32	1.93	12.88	0.47	323.13	42.88	40.25	236.75	4.02	44.54
146	8.83	39.13	1.18	2098.75	10.75	13.63	28.00	0.35	2.06	14.38	0.51	445.63					
147	8.32	38.42	1.17	2071.25	10.67	13.75	29.50	0.36	2.15	15.75	0.54	494.58	43.75	41.33	237.33	3.99	42.61
148	6.96	34.25	1.11	1783.75	10.63	13.63	27.00	0.33	1.98	13.38	0.49	383.75	43.88	44.88	230.00	3.81	36.51
149	8.04	40.50	1.16	2096.25	10.75	13.75	28.25	0.35	2.05	14.50	0.51	440.00	42.88	41.13	243.38	4.04	43.32
150	8.52	39.50	1.17	2141.25	10.50	13.75	27.50	0.33	2.00	13.75	0.49	378.75	44.00	40.75	242.50	4.03	44.70
151	8.73	38.63	1.18	2097.50	10.50	13.88	26.50	0.31	1.91	12.63	0.46	310.63	43.25	39.50	241.88	4.05	47.83
153	7.52	35.88	1.14	1876.88	10.63	13.88	27.13	0.32	1.95	13.25	0.48	353.75	42.88	42.13	238.13	3.95	41.46
154	6.64	32.92	1.10	1740.83	11.75	14.50	24.75	0.26	1.71	10.25	0.39	251.25	45.08	42.83	222.92	3.85	39.86
155	7.09	35.00	1.12	1868.75	11.75	14.75	25.25	0.26	1.71	10.50	0.39	240.00	44.88	43.13	224.88	3.85	40.15
156	6.83	35.00	1.11	1845.00	11.88	14.75	24.75	0.25	1.68	10.00	0.38	226.88	45.38	44.25	211.75	3.67	35.59
157	7.17	37.00	1.12	1992.50	12.00	14.75	25.25	0.26	1.71	10.50	0.39	263.75	45.50	43.75	217.75	3.77	36.59
158	7.22	35.00	1.12	1880.63	12.00	14.75	25.38	0.26	1.72	10.63	0.39	270.00	45.38	43.13	226.75	3.86	40.40
159	8.43	39.00	1.17	2068.75	10.75	13.75	27.00	0.33	1.96	13.25	0.48	377.50	43.00	40.50	242.00	4.05	44.70
170	7.67	35.00	1.14	1845.00	10.38	12.88	27.25	0.36	2.12	14.38	0.53	481.25	40.88	44.75	196.75	3.55	31.73
171	6.01	29.44	1.06	1525.31	10.44	11.50	26.25	0.39	2.28	14.75	0.58	636.56	38.63	38.13	159.44	3.58	27.20
172	5.32	26.67	1.01	1412.49	10.83	12.08	24.50	0.34	2.03	12.42	0.50	502.08	40.33	41.08	127.50	2.87	19.19
173	5.41	32.00	1.02	1671.25	10.50	11.50	33.50	0.49	2.91	22.00	0.73	1005.00	46.50	51.75	149.75	2.66	17.67
174	7.27	34.50	1.13	1796.25	10.00	13.00	27.50	0.36	2.12	14.50	0.53	440.00	43.25	51.25	192.88	3.30	26.09
175	6.68	35.50	1.10	1870.00	11.50	12.25	31.50	0.44	2.57	19.25	0.65	891.25	46.13	49.00	169.25	3.03	22.36
176	5.36	28.88	1.02	1515.00	10.63	12.13	30.00	0.42	2.47	17.88	0.63	751.25	47.00	51.25	155.13	2.85	18.95
177	6.93	33.38	1.11	1751.88	11.00	12.50	30.75	0.42	2.46	18.25	0.63	770.00	44.00	48.13	168.50	3.14	22.93
178	3.59	22.00	0.84	1052.50	11.75	12.50	31.00	0.43	2.48	18.50	0.63	853.75	49.25	60.00	135.75	2.19	13.60
179	5.48	30.25	1.03	1560.00	11.25	12.25	31.50	0.44	2.57	19.25	0.65	867.50	46.25	54.00	155.25	2.73	17.86
180	3.93	22.00	0.88	1123.75	11.50	12.50	29.25	0.40	2.34	16.75	0.59	742.50	47.50	55.00	132.50	2.37	14.60
181	4.84	27.38	0.97	1404.38	11.50	12.63	30.75	0.42	2.44	18.13	0.62	799.38	47.75	56.50	151.25	2.60	16.56
182	6.67	34.00	1.10	1771.25	11.00	11.92	32.33	0.46	2.71	20.42	0.68	933.74	44.83	50.08	174.33	3.11	22.41
183	7.52	39.13	1.14	2063.13	11.25	12.25	35.38	0.49	2.89	23.13	0.72	1061.25	43.88	49.00	190.38	3.26	25.64

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
184	4.31	24.00	0.92	1200.00	10.25	12.25	29.50	0.41	2.41	17.25	0.61	672.50	45.50	54.25	136.75	2.46	15.38
221	7.57	37.75	1.14	2006.25	10.50	13.75	27.75	0.34	2.02	14.00	0.50	391.25	47.25	51.00	229.50	3.63	35.08
222	7.95	36.50	1.15	1991.25	10.50	13.50	26.25	0.32	1.94	12.75	0.48	352.50	46.50	50.00	228.50	3.67	36.09
223	8.95	41.75	1.19	2206.25	10.75	15.00	30.00	0.33	2.00	15.00	0.49	346.25	42.00	40.75	252.00	4.08	47.63
224	9.35	41.75	1.20	2277.50	10.50	13.75	27.75	0.34	2.02	14.00	0.50	391.25	42.75	41.50	241.75	3.99	43.99
225	8.81	41.00	1.18	2216.25	10.75	13.75	30.00	0.37	2.18	16.25	0.55	527.50	43.25	41.00	244.00	4.02	45.66
300	10.09	43.92	1.22	2354.17	10.50	12.67	34.25	0.46	2.70	21.58	0.68	873.33	41.83	39.17	256.50	4.19	48.00
301	9.40	42.00	1.20	2226.67	10.25	13.08	31.75	0.42	2.43	18.67	0.62	664.17	41.25	39.33	249.42	4.15	47.72
302	9.16	42.31	1.19	2252.19	10.38	12.88	31.00	0.41	2.41	18.13	0.61	668.75	41.88	40.00	257.75	4.18	46.51
303	9.27	42.88	1.20	2304.06	10.63	12.56	34.75	0.47	2.77	22.19	0.70	925.31	44.25	42.94	217.25	3.79	35.89
304	8.90	41.50	1.19	2193.75	10.25	13.75	31.75	0.40	2.31	18.00	0.59	567.50	41.50	41.00	257.50	4.12	47.52
305	9.12	41.63	1.19	2211.88	10.13	13.75	31.75	0.40	2.31	18.00	0.59	555.63	41.63	38.88	259.38	4.24	51.94
306	10.00	42.75	1.22	2303.75	10.17	13.00	31.92	0.42	2.46	18.92	0.62	676.67	41.83	40.17	255.50	4.15	46.75
307	8.64	38.83	1.18	2052.51	9.92	12.25	30.83	0.43	2.52	18.58	0.64	707.50					
308	10.70	46.08	1.23	2470.41	10.17	12.50	34.00	0.46	2.72	21.50	0.69	853.33	42.42	40.50	252.75	4.13	45.46
309	10.05	45.25	1.22	2428.75	10.00	11.75	30.50	0.44	2.60	18.75	0.66	771.25	41.25	39.00	240.25	4.08	43.63
310	9.68	43.42	1.21	2305.42	10.58	13.00	33.33	0.44	2.56	20.33	0.65	787.08	41.67	39.67	249.17	4.12	46.09
311	9.27	42.38	1.20	2285.00	10.38	12.50	32.88	0.45	2.63	20.38	0.67	816.88	42.25	44.13	241.00	3.91	37.51
312	10.21	44.50	1.22	2383.33	10.33	12.67	33.42	0.45	2.64	20.75	0.67	815.84	41.75	38.42	260.00	4.25	49.28
313	9.63	42.42	1.21	2255.41	10.25	13.08	31.00	0.41	2.37	17.92	0.60	626.67	41.42	39.33	256.92	4.19	48.14
314	9.25	41.25	1.20	2181.25	10.25	12.75	30.75	0.41	2.41	18.00	0.61	662.50	41.75	39.50	247.00	4.10	46.88
315	7.15	36.88	1.12	1974.38	10.13	10.63	32.38	0.51	3.05	21.75	0.75	1040.00	45.25	45.25	205.13	3.64	28.83
316	10.11	43.25	1.22	2328.75	10.25	13.50	31.25	0.40	2.31	17.75	0.59	578.75	41.50	39.50	250.75	4.14	48.97
434	6.33	32.00	1.08	1671.25	11.63	14.63	25.00	0.26	1.71	10.38	0.39	233.75	45.13	43.25	225.38	3.85	40.11
435	7.70	36.88	1.14	1986.25	12.25	14.63	27.25	0.30	1.86	12.63	0.45	405.63	45.25	42.88	222.25	3.82	39.83
436	6.88	35.25	1.11	1857.50	11.75	15.00	26.50	0.28	1.77	11.50	0.41	266.25	44.50	43.75	210.00	3.69	35.85
437	8.87	40.31	1.18	2146.25	10.56	13.75	28.81	0.35	2.10	15.06	0.52	450.31					
438	8.27	37.58	1.16	2005.83	10.50	13.75	26.83	0.32	1.95	13.08	0.48	345.41	42.58	40.67	237.92	3.99	44.09
439	7.62	34.75	1.14	1856.25	10.50	13.50	27.50	0.34	2.04	14.00	0.51	415.00	44.25	47.75	219.25	3.61	35.32
440	8.31	37.75	1.17	2030.00	10.58	13.75	27.50	0.33	2.00	13.75	0.49	386.67	43.33	41.42	239.17	3.97	44.83
441	8.55	37.75	1.17	2030.00	10.75	14.00	27.25	0.32	1.95	13.25	0.48	353.75	42.13	41.50	231.88	3.91	43.48
442	9.56	41.75	1.20	2289.38	11.25	13.38	31.25	0.40	2.34	17.88	0.59	691.88					
443	7.76	38.88	1.15	2015.00	10.50	13.63	29.38	0.37	2.16	15.75	0.54	490.63	42.63	42.75	231.88	3.91	39.22
444	8.48	39.25	1.17	2081.25	10.75	13.75	27.75	0.34	2.02	14.00	0.50	415.00					
445	6.67	34.00	1.10	1795.00	12.00	14.75	25.75	0.27	1.75	11.00	0.40	288.75	45.50	43.75	229.50	3.84	40.76
458	5.88	31.33	1.05	1622.08	10.83	12.42	30.58	0.42	2.46	18.17	0.63	757.91	45.33	51.33	167.33	2.99	21.01
459	5.71	30.63	1.04	1602.50	11.00	12.75	30.75	0.41	2.41	18.00	0.61	733.75	46.63	54.00	157.13	2.76	18.45
461	5.85	31.50	1.05	1646.25	10.75	12.00	32.50	0.46	2.71	20.50	0.68	906.25	45.50	51.50	166.00	2.96	20.36
462	4.16	25.25	0.91	1215.00	10.75	12.25	31.25	0.44	2.55	19.00	0.65	807.50	47.25	55.75	155.00	2.70	16.84
463	5.96	32.25	1.06	1660.00	10.50	11.75	31.42	0.46	2.67	19.67	0.68	864.59	46.08	51.25	164.17	2.96	20.14
464	6.63	32.38	1.09	1690.00	11.25	12.25	30.00	0.42	2.45	17.75	0.62	792.50	44.38	46.38	166.13	3.17	23.67
465	7.89	39.63	1.15	2016.88	10.63	11.31	31.25	0.47	2.76	19.94	0.69	931.56	40.44	42.81	211.25	3.74	32.57
466	6.54	34.63	1.09	1814.38	11.00	11.88	32.63	0.47	2.75	20.75	0.69	954.38	44.88	49.38	176.63	3.15	23.11
467	6.71	37.13	1.10	1951.25	10.25	11.00	31.88	0.49	2.90	20.88	0.72	972.50	43.63	50.00	161.13	2.88	20.07
468	5.12	29.38	1.00	1498.44	10.75	12.00	31.88	0.45	2.66	19.88	0.67	875.00	45.81	54.25	143.13	2.49	16.10
470	4.86	27.00	0.98	1397.50	11.50	12.25	31.50	0.44	2.57	19.25	0.65	891.25	49.00	54.75	145.75	2.58	16.38
471	5.68	36.25	1.04	1812.50	10.75	12.50	30.25	0.42	2.42	17.75	0.62	721.25	45.75	51.25	196.50	3.24	24.28
472	6.35	34.75	1.08	1856.25	10.25	11.25	32.75	0.49	2.91	21.50	0.72	980.00	46.63	50.50	154.13	2.78	19.12

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
473	8.63	36.25	1.18	1919.38	10.13	12.75	27.50	0.37	2.16	14.75	0.54	488.13	38.75	42.88	191.50	3.55	32.16
474	8.58	36.00	1.17	1918.75	9.88	12.75	27.00	0.36	2.12	14.25	0.53	439.38	39.25	45.25	196.00	3.52	31.36
475	8.00	35.88	1.15	1900.63	10.63	13.13	28.00	0.36	2.13	14.88	0.54	506.25	41.25	45.50	192.25	3.45	30.48
476	6.37	34.88	1.08	1862.50	10.25	11.13	31.50	0.48	2.83	20.38	0.71	935.63	47.63	49.63	153.13	2.83	19.17
477	6.08	31.33	1.06	1645.83	10.58	11.42	25.67	0.38	2.25	14.25	0.57	633.34	39.08	39.42	142.33	3.11	22.42
478	6.00	30.00	1.06	1606.88	10.38	11.50	25.00	0.37	2.17	13.50	0.55	568.13	38.13	38.63	137.63	3.11	22.23
479	8.28	36.38	1.16	1925.63	11.63	12.25	30.75	0.43	2.51	18.50	0.64	865.63	44.50	44.13	180.50	3.41	28.26
480	6.92	38.50	1.11	2043.75	10.50	11.25	33.50	0.50	2.98	22.25	0.74	1041.25	45.50	49.75	177.00	3.08	22.36
481	7.95	34.75	1.15	1832.50	10.38	12.88	28.00	0.37	2.17	15.13	0.55	518.75	39.75	45.50	190.75	3.49	29.38
482	7.19	36.38	1.12	1854.38	10.50	12.63	28.25	0.38	2.24	15.63	0.57	579.38	39.88	43.75	198.38	3.62	30.36
483	7.62	34.75	1.14	1832.50	11.00	13.50	29.50	0.37	2.19	16.00	0.55	562.50	41.25	46.25	186.25	3.38	28.94
484	5.65	30.25	1.04	1583.75	10.50	11.75	27.25	0.40	2.32	15.50	0.59	656.25	39.75	40.50	142.00	3.16	21.73
485	5.60	28.75	1.03	1532.50	12.00	12.75	26.50	0.35	2.08	13.75	0.52	616.25	42.75	40.75	132.00	2.95	20.34
486	9.63	43.13	1.21	2275.00	9.38	10.88	29.25	0.46	2.69	18.38	0.68	776.25	39.88	41.88	211.50	3.67	36.31
487	6.20	32.50	1.07	1648.75	10.75	12.25	25.00	0.34	2.04	12.75	0.51	495.00	40.25	39.00	146.75	3.25	24.18
488	5.09	28.13	1.00	1430.00	10.38	11.63	28.25	0.42	2.43	16.63	0.62	712.50	46.88	54.25	147.63	2.63	16.89
489	5.46	31.50	1.02	1551.25	10.56	12.00	33.25	0.47	2.77	21.25	0.70	925.94	38.00	43.00	196.50	3.80	28.93
490	6.55	36.75	1.09	1932.50	10.63	11.75	32.75	0.47	2.79	21.00	0.70	943.13	48.00	50.63	181.50	3.11	23.45
498	9.10	42.50	1.19	2243.75	10.75	15.00	27.50	0.29	1.83	12.50	0.44	221.25	43.50	44.50	261.00	4.04	42.75
499	6.44	35.38	1.09	1792.50	10.50	12.88	29.00	0.39	2.25	16.13	0.57	580.63	47.00	51.38	219.25	3.50	29.90
500	8.84	37.25	1.18	2028.75	10.50	13.50	27.50	0.34	2.04	14.00	0.51	415.00	42.50	42.00	234.00	3.90	42.70
501	10.00	44.25	1.22	2410.42	11.42	14.33	31.08	0.37	2.17	16.75	0.55	560.41	44.67	40.67	257.83	4.14	48.83
502	9.73	43.63	1.21	2395.00	11.13	14.38	31.63	0.38	2.20	17.25	0.56	553.75	44.63	41.13	260.50	4.15	48.80
503	9.40	42.00	1.20	2297.92	11.25	14.67	29.92	0.34	2.04	15.25	0.51	437.92	44.42	40.25	256.50	4.17	48.96
504	9.15	42.46	1.19	2293.13	10.83	13.58	33.50	0.42	2.47	19.92	0.63	734.58	43.63	39.67	254.83	4.18	48.42
505	8.72	39.06	1.18	2137.19	10.81	14.44	28.50	0.33	1.97	14.06	0.49	358.75	43.31	43.50	236.25	3.89	41.89
506	9.84	42.00	1.21	2313.75	10.50	14.00	28.75	0.35	2.05	14.75	0.51	405.00	42.75	40.75	248.25	4.05	45.70
507	8.53	38.80	1.17	2096.75	10.80	13.65	26.90	0.33	1.97	13.25	0.48	391.75	45.10	43.00	244.40	4.01	43.61
508	9.05	40.25	1.19	2178.75	10.67	13.83	28.42	0.35	2.05	14.58	0.51	428.34	43.67	40.08	258.17	4.19	48.92
509	7.72	36.13	1.14	1936.88	11.25	14.50	31.25	0.37	2.16	16.75	0.54	528.75	43.13	41.00	233.63	4.03	41.37
510	7.39	38.95	1.13	1995.00	10.75	13.80	27.75	0.34	2.01	13.95	0.50	407.75					
511	7.42	39.08	1.13	1985.84	10.75	14.58	28.58	0.32	1.96	14.00	0.48	335.83					
512	9.05	42.25	1.19	2278.75	11.00	14.00	27.50	0.33	1.96	13.50	0.48	390.00	44.92	44.25	248.17	3.97	42.90
513	9.05	40.25	1.19	2202.50	10.75	13.75	27.75	0.34	2.02	14.00	0.50	415.00	45.00	44.25	235.00	3.93	38.82
514	9.02	42.13	1.19	2248.75	11.50	13.75	30.00	0.37	2.18	16.25	0.55	598.75	43.75	39.50	250.50	4.11	48.31
515	7.39	36.75	1.13	1956.25	10.50	13.63	26.75	0.33	1.96	13.13	0.48	359.38	46.63	51.63	226.63	3.59	32.85
516	9.02	40.08	1.19	2178.33	10.58	13.42	29.58	0.38	2.20	16.17	0.56	539.16	43.50	43.17	235.67	3.88	41.28
517	9.30	41.50	1.20	2217.50	10.75	13.50	33.50	0.43	2.48	20.00	0.63	738.75	44.25	43.50	229.00	3.82	39.45
518	8.14	37.50	1.16	2017.50	10.50	13.50	28.00	0.35	2.07	14.50	0.52	440.00	43.75	44.88	229.88	3.81	38.77
519	7.70	36.88	1.14	1926.88	10.38	13.25	27.75	0.35	2.09	14.50	0.52	451.88	45.13	48.13	217.38	3.59	32.94
520	7.33	37.19	1.13	1942.50	10.44	12.63	30.00	0.41	2.38	17.38	0.60	660.94	48.00	53.63	214.56	3.40	28.69
521	9.97	43.75	1.22	2389.38	10.75	14.38	29.63	0.35	2.06	15.25	0.51	418.13	43.50	40.50	258.38	4.15	49.11
522	9.02	42.13	1.19	2272.50	10.75	13.88	29.75	0.36	2.14	15.88	0.54	496.88	43.25	39.25	252.75	4.14	49.18
523	9.10	42.50	1.19	2220.00	11.00	14.00	31.38	0.38	2.24	17.38	0.57	583.75	43.63	40.25	264.38	4.23	47.85
524	8.15	42.00	1.16	2147.50	10.75	13.25	31.13	0.40	2.35	17.88	0.60	656.25	42.63	41.25	262.38	4.15	44.88
525	8.38	38.75	1.17	2103.75	10.75	13.63	29.38	0.37	2.16	15.75	0.54	514.38	45.13	45.75	235.25	3.81	39.23
526	10.05	43.00	1.22	2363.75	10.75	14.00	30.50	0.37	2.18	16.50	0.55	516.25	43.00	38.75	258.50	4.23	51.28
527	9.95	42.50	1.21	2291.25	10.75	14.00	28.25	0.34	2.02	14.25	0.50	403.75	42.50	40.00	246.75	4.05	47.78

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
528	8.85	40.25	1.18	2143.13	10.75	14.00	27.50	0.33	1.96	13.50	0.48	366.25	44.25	40.25	256.13	4.16	48.56
529	7.65	38.25	1.14	2031.25	10.50	13.50	27.38	0.34	2.03	13.88	0.50	408.75	48.00	54.63	226.38	3.51	31.65
530	9.85	44.25	1.21	2402.50	10.75	14.00	30.75	0.37	2.20	16.75	0.56	528.75	43.50	40.25	260.50	4.18	48.89
531	9.32	43.00	1.20	2308.34	10.67	13.92	29.92	0.37	2.15	16.00	0.54	491.25	43.58	41.08	257.33	4.14	46.38
532	9.85	44.25	1.21	2402.50	10.75	13.50	30.50	0.39	2.26	17.00	0.57	588.75	43.25	39.00	259.00	4.21	49.92
533	8.43	39.00	1.17	2068.75	11.25	13.75	27.75	0.34	2.02	14.00	0.50	462.50	44.25	41.25	250.50	4.07	46.01
534	6.46	35.50	1.09	1790.83	10.58	13.25	27.92	0.36	2.11	14.67	0.53	480.00	44.67	49.25	218.00	3.57	31.03
535	6.79	37.05	1.10	1900.00	10.90	13.70	28.25	0.35	2.06	14.55	0.51	461.50	45.00	47.20	237.60	3.79	35.93
536	8.67	40.25	1.18	2178.75	10.50	13.75	27.75	0.34	2.02	14.00	0.50	391.25	44.50	43.00	247.25	3.98	44.23
537	8.62	40.00	1.18	2118.75	10.50	13.75	27.75	0.34	2.02	14.00	0.50	391.25	43.00	43.00	240.50	3.92	40.72
538	8.20	39.63	1.16	2129.69	11.19	14.56	28.25	0.32	1.94	13.69	0.47	363.75	43.50	42.31	242.88	3.99	43.47
539	8.71	40.50	1.18	2191.25	11.50	14.75	28.25	0.31	1.92	13.50	0.47	366.25	44.00	41.25	241.00	4.03	45.09
540	8.07	37.13	1.16	1998.75	10.50	13.75	26.50	0.32	1.93	12.75	0.47	328.75	46.25	46.88	233.00	3.82	38.31
541	10.10	44.38	1.22	2432.50	11.50	13.63	34.25	0.43	2.51	20.63	0.64	829.38	45.00	38.75	266.88	4.29	51.30
542	9.90	43.38	1.21	2346.88	10.75	15.00	30.63	0.34	2.04	15.63	0.51	377.50	44.38	42.50	259.63	4.10	47.21
543	7.61	38.00	1.14	2018.75	10.25	13.25	29.50	0.38	2.23	16.25	0.56	527.50	46.75	48.75	236.50	3.73	35.71
544	8.24	38.00	1.16	2066.25	10.75	13.75	26.25	0.31	1.91	12.50	0.46	340.00	46.25	46.75	236.75	3.80	39.70
545	8.68	39.67	1.18	2141.66	11.08	13.75	29.50	0.36	2.15	15.75	0.54	534.17	45.58	43.50	244.92	3.94	44.15
546	9.60	43.00	1.21	2340.00	10.25	13.50	26.50	0.33	1.96	13.00	0.48	341.25	44.50	43.50	243.50	3.97	42.61
547	9.90	44.50	1.21	2438.75	11.25	14.75	32.50	0.38	2.20	17.75	0.56	555.00	44.00	41.25	260.50	4.15	48.46
571	8.00	40.25	1.16	2131.25	10.25	10.75	36.25	0.54	3.37	25.50	0.81	1227.50	45.00	48.75	196.25	3.37	26.04
20	5.68	27.81	1.04	1426.25	7.69	7.69	42.13	0.69	5.48	34.44	1.03	1721.88	42.81	49.56	147.44	2.68	19.02
21	5.72	27.44	1.04	1413.44	8.56	8.44	37.75	0.63	4.47	29.31	0.94	1477.50	42.00	48.94	140.94	2.65	18.15
22	6.22	29.12	1.07	1527.50	7.88	7.67	42.08	0.69	5.49	34.42	1.03	1740.62					
23	5.68	28.06	1.04	1438.75	8.13	8.00	42.00	0.68	5.25	34.00	1.01	1711.88	44.19	51.81	149.50	2.63	18.61
24	5.56	27.75	1.03	1419.16	8.00	8.00	42.75	0.68	5.34	34.75	1.02	1737.50	43.33	50.75	149.92	2.67	18.78
25	5.24	24.92	1.01	1289.38	9.00	8.96	36.25	0.60	4.05	27.29	0.90	1368.54	43.25	48.08	133.08	2.57	17.13
26	5.97	28.88	1.06	1479.38	8.06	7.25	41.81	0.70	5.77	34.56	1.05	1805.31	42.06	49.25	148.81	2.71	19.61
27	5.55	28.44	1.03	1427.81	8.06	7.81	42.06	0.69	5.38	34.25	1.02	1736.25	42.13	51.81	151.88	2.67	18.79
28	4.63	24.50	0.95	1201.25	7.58	7.58	42.50	0.70	5.60	34.92	1.04	1745.83					
29	6.09	29.46	1.06	1534.28	7.86	7.43	43.82	0.71	5.90	36.39	1.05	1860.36	43.25	51.36	154.61	2.71	19.81
30	6.08	29.45	1.06	1515.25	7.75	7.30	43.95	0.72	6.02	36.65	1.06	1875.25	43.50	49.95	152.90	2.73	20.00
31	5.89	29.10	1.05	1493.00	8.05	7.68	43.03	0.70	5.61	35.35	1.04	1803.13					
32	6.57	30.75	1.09	1613.50	7.70	7.30	43.63	0.71	5.98	36.33	1.06	1854.25					
33	5.11	26.54	1.00	1331.04	7.63	7.33	40.33	0.69	5.50	33.00	1.03	1677.71					
34	3.55	20.69	0.83	989.86	9.00	8.97	40.81	0.64	4.55	31.83	0.95	1594.30	48.33	57.92	144.00	2.34	15.32
35	3.32	19.70	0.79	909.00	9.30	8.95	40.40	0.64	4.51	31.45	0.95	1605.75	49.85	59.35	145.10	2.32	15.08
36	3.56	20.90	0.83	992.75	8.95	8.45	41.20	0.66	4.88	32.75	0.98	1685.00	49.05	59.10	145.60	2.32	15.47
37	3.40	19.79	0.81	942.09	8.92	8.79	40.63	0.64	4.62	31.83	0.96	1603.54	47.92	58.29	143.88	2.34	15.26
38	3.52	20.75	0.82	974.17	8.79	8.71	40.46	0.65	4.65	31.75	0.96	1595.41	48.21	59.13	146.46	2.35	15.41
39	3.37	20.04	0.80	922.92	9.25	8.88	41.79	0.65	4.71	32.92	0.96	1681.46	48.79	59.50	145.00	2.29	15.12
40	3.43	19.88	0.81	981.88	9.08	9.08	40.46	0.63	4.45	31.37	0.94	1568.75	50.25	57.88	141.83	2.30	15.04
41	3.97	22.06	0.88	1097.19	8.81	8.69	40.06	0.64	4.61	31.38	0.96	1580.63	49.06	57.50	144.88	2.38	15.79
42	3.91	23.60	0.88	1132.50	8.45	8.75	41.05	0.65	4.69	32.30	0.96	1586.50	50.15	62.25	158.10	2.45	16.08
43	3.36	20.25	0.80	972.91	9.00	8.33	42.08	0.67	5.05	33.75	0.99	1750.83	51.25	59.17	145.17	2.29	15.40
98	2.84	16.21	0.71	711.46	9.25	9.38	37.21	0.60	3.97	27.83	0.89	1379.79	47.04	58.04	132.00	2.15	13.76
99	2.89	16.46	0.72	767.51	9.08	9.33	38.46	0.61	4.12	29.12	0.90	1432.50	47.92	59.00	131.79	2.08	13.64
100	3.44	20.00	0.81	1000.00	8.75	8.63	41.94	0.66	4.86	33.31	0.98	1677.50	50.13	58.88	140.63	2.21	14.98

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
101	3.42	20.00	0.81	976.25	8.63	8.69	41.44	0.65	4.77	32.75	0.97	1631.56	49.13	58.38	140.81	2.24	15.02
102	3.61	21.00	0.84	1054.75	10.05	10.80	36.35	0.54	3.37	25.55	0.80	1206.25	50.30	60.05	138.20	2.19	13.98
103	3.31	18.19	0.79	873.75	8.25	8.50	39.25	0.64	4.62	30.75	0.96	1513.75	45.50	54.94	133.81	2.28	14.98
104	3.03	17.25	0.74	791.25	8.50	8.75	39.00	0.63	4.46	30.25	0.94	1488.75	46.75	58.00	135.75	2.20	14.39
105	2.97	16.75	0.73	778.13	9.50	9.50	36.75	0.59	3.87	27.25	0.87	1362.50	48.25	58.00	133.50	2.19	13.92
106	2.99	17.63	0.74	798.13	9.25	9.75	38.25	0.59	3.92	28.50	0.88	1377.50	50.50	62.50	140.00	2.13	13.73
185	5.62	27.13	1.03	1391.88	7.88	7.00	42.13	0.72	6.02	35.13	1.06	1839.38	47.13	52.00	152.50	2.68	19.49
186	5.99	28.67	1.06	1480.84	8.50	9.00	34.67	0.59	3.85	25.67	0.87	1235.84	48.08	54.50	151.67	2.64	18.09
187	7.40	30.92	1.13	1632.92	7.67	8.42	34.08	0.60	4.05	25.67	0.90	1212.08					
188	6.16	28.38	1.07	1490.00	7.75	7.25	40.00	0.69	5.52	32.75	1.03	1685.00					
189	6.09	29.25	1.06	1510.00	8.00	7.75	41.50	0.69	5.35	33.75	1.02	1711.25	47.50	53.00	155.00	2.68	19.34
190	5.20	26.25	1.00	1383.75	8.17	7.42	42.08	0.70	5.67	34.67	1.04	1804.58	48.50	51.00	151.17	2.72	19.03
191	7.18	31.92	1.12	1682.91	7.92	8.50	34.00	0.60	4.00	25.50	0.89	1219.58	46.00	52.25	156.42	2.80	20.04
192	7.05	30.25	1.11	1607.50	7.75	6.50	40.00	0.72	6.15	33.50	1.07	1793.75					
193	6.55	30.08	1.09	1551.67	8.67	10.58	31.67	0.50	2.99	21.08	0.74	872.09					
194	5.33	26.33	1.01	1372.09	8.00	6.92	42.00	0.72	6.07	35.08	1.06	1857.08	47.92	51.58	151.58	2.69	19.34
195	4.89	26.25	0.98	1312.50	8.25	7.58	42.00	0.69	5.54	34.42	1.03	1784.17	49.08	54.42	154.00	2.61	18.27
196	7.86	31.75	1.15	1718.13	7.75	8.00	38.25	0.65	4.78	30.25	0.97	1488.75	44.63	50.25	156.75	2.86	21.41
197	7.38	31.13	1.13	1675.00	7.75	7.00	41.50	0.71	5.93	34.50	1.06	1796.25	44.00	48.88	156.75	2.86	21.94
237	6.00	29.38	1.06	1528.13	7.88	7.50	43.25	0.70	5.77	35.75	1.05	1823.13	44.75	50.94	153.75	2.72	19.67
238	5.80	27.58	1.05	1426.66	8.92	8.67	37.17	0.62	4.29	28.50	0.92	1448.75	42.58	48.33	138.00	2.62	17.95
239	4.56	24.33	0.95	1185.01	7.67	7.58	41.25	0.69	5.44	33.67	1.02	1691.25					
240	4.92	25.83	0.98	1299.59	8.08	7.92	40.17	0.67	5.07	32.25	1.00	1628.34					
241	4.36	21.00	0.93	1073.75	9.00	8.50	36.50	0.62	4.29	28.00	0.92	1447.50	42.00	45.25	123.00	2.52	16.41
242	5.42	26.50	1.02	1372.50	8.75	8.38	39.63	0.65	4.73	31.25	0.97	1598.13	43.75	49.38	142.63	2.65	18.09
243	6.12	29.44	1.07	1543.13	7.94	7.81	41.00	0.68	5.25	33.19	1.01	1671.25					
244	5.18	26.63	1.00	1366.88	8.38	8.13	41.63	0.67	5.12	33.50	1.00	1698.75	43.88	51.88	146.63	2.58	17.91
245	5.67	28.00	1.04	1447.50	8.00	7.25	43.58	0.71	6.01	36.33	1.06	1887.91	44.25	50.67	151.50	2.70	19.49
246	5.33	26.00	1.01	1335.63	8.25	7.75	41.75	0.69	5.39	34.00	1.02	1747.50	40.25	45.50	136.63	2.66	18.60
247	5.16	26.50	1.00	1336.88	7.88	7.75	41.25	0.68	5.32	33.50	1.02	1686.88					
248	3.56	20.13	0.83	1041.88	9.50	9.38	39.75	0.62	4.24	30.38	0.92	1530.63	50.50	58.38	142.38	2.32	15.00
249	3.20	19.25	0.78	867.50	9.25	9.25	40.75	0.63	4.41	31.50	0.94	1575.00	50.25	58.25	142.25	2.30	14.84
250	3.90	21.75	0.88	1087.50	9.00	9.00	41.25	0.64	4.58	32.25	0.95	1612.50	47.50	56.50	143.00	2.37	15.67
251	3.40	19.63	0.81	951.56	9.25	9.38	40.63	0.63	4.33	31.25	0.93	1550.63	50.69	58.56	142.31	2.30	14.89
252	3.31	18.88	0.79	955.63	9.25	9.25	40.88	0.63	4.42	31.63	0.94	1581.25	51.06	58.50	140.75	2.26	14.76
253	4.30	23.67	0.92	1207.08	8.42	8.00	40.17	0.67	5.02	32.17	0.99	1647.92	48.25	54.17	142.33	2.43	16.55
254	4.25	22.75	0.92	1173.13	8.13	8.25	41.88	0.67	5.08	33.63	1.00	1669.38	48.63	56.38	147.13	2.45	16.61
255	3.56	20.50	0.83	977.50	8.75	8.38	41.50	0.66	4.96	33.13	0.99	1691.88	48.75	57.88	145.00	2.36	15.70
256	3.32	19.25	0.79	926.88	9.13	9.00	39.56	0.63	4.40	30.56	0.93	1540.00	50.25	58.19	141.13	2.30	14.90
257	4.29	23.88	0.92	1205.63	8.75	8.75	41.00	0.65	4.69	32.25	0.96	1612.50	48.88	57.50	148.00	2.42	16.23
258	4.10	22.50	0.90	1172.50	8.50	8.00	41.13	0.67	5.14	33.13	1.00	1703.75	50.00	57.25	149.63	2.47	16.66
259	2.87	15.75	0.71	716.25	11.06	12.50	32.13	0.44	2.57	19.63	0.65	844.69	47.75	59.00	124.75	2.05	12.58
260	4.11	21.38	0.90	1092.50	8.25	8.25	40.63	0.66	4.92	32.38	0.98	1618.75	44.69	51.75	139.38	2.51	16.65
261	3.55	21.00	0.83	978.75	9.00	9.25	40.75	0.63	4.41	31.50	0.94	1551.25	49.00	59.00	145.75	2.34	15.19
262	3.56	20.50	0.83	1001.25	9.17	9.08	40.00	0.63	4.40	30.92	0.94	1553.75	49.58	57.92	143.75	2.35	15.25
263	3.63	21.00	0.84	1061.88	9.00	8.75	40.00	0.64	4.57	31.25	0.95	1586.25	49.13	56.75	142.38	2.36	15.46
264	3.66	20.83	0.84	1010.01	8.42	8.25	41.00	0.66	4.97	32.75	0.99	1653.33	48.00	56.00	142.50	2.38	15.85
265	3.73	20.50	0.85	1025.00	9.00	8.75	41.00	0.65	4.69	32.25	0.96	1636.25	48.00	55.50	142.25	2.41	15.83

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
266	3.41	20.50	0.81	977.50	9.00	8.75	40.00	0.64	4.57	31.25	0.95	1586.25	49.50	60.50	146.50	2.31	15.12
267	4.03	22.00	0.89	1147.50	9.25	9.50	41.25	0.63	4.34	31.75	0.93	1563.75	51.25	58.00	145.00	2.35	15.56
268	3.53	19.00	0.83	997.50	9.25	9.25	40.25	0.63	4.35	31.00	0.93	1550.00	50.00	57.50	137.75	2.25	14.81
269	3.20	19.25	0.78	867.50	9.25	8.50	42.25	0.67	4.97	33.75	0.99	1758.75	49.50	58.25	145.25	2.34	15.44
270	3.93	21.25	0.88	1086.25	8.00	8.50	38.50	0.64	4.53	30.00	0.95	1452.50	44.75	53.75	137.00	2.38	15.75
360	2.83	16.00	0.71	740.63	9.25	9.50	38.38	0.60	4.04	28.88	0.90	1420.00	48.63	59.00	132.00	2.09	13.59
361	2.89	16.50	0.72	765.63	9.00	9.13	38.50	0.62	4.22	29.38	0.92	1456.88	48.25	59.00	131.38	2.07	13.66
362	2.98	17.00	0.74	762.91	9.25	9.50	37.67	0.60	3.96	28.17	0.89	1384.59	47.92	57.58	133.25	2.19	13.98
363	2.96	16.63	0.73	783.75	9.25	9.38	38.38	0.61	4.09	29.00	0.90	1438.13	48.13	58.00	133.38	2.16	13.96
364	3.04	17.44	0.75	794.69	9.06	8.88	39.00	0.63	4.39	30.13	0.93	1524.06	47.69	58.50	137.25	2.22	14.42
365	3.52	20.58	0.83	1013.33	9.17	9.17	40.67	0.63	4.44	31.50	0.94	1575.00	50.25	59.75	141.42	2.21	14.72
366	3.17	18.75	0.77	878.13	8.50	8.50	41.00	0.66	4.82	32.50	0.98	1625.00	49.38	59.13	140.50	2.23	14.85
367	3.44	19.94	0.81	949.38	8.63	8.69	40.75	0.65	4.69	32.06	0.96	1597.19	48.25	57.69	142.00	2.31	15.23
368	3.56	20.31	0.83	1009.69	9.06	9.13	38.44	0.62	4.21	29.31	0.91	1459.69	49.81	58.38	138.19	2.22	14.63
369	2.79	16.44	0.70	720.94	8.94	9.19	36.38	0.60	3.96	27.19	0.89	1335.63	50.06	61.50	136.38	2.12	13.61
370	3.32	20.08	0.79	925.00	9.42	9.67	38.33	0.60	3.97	28.67	0.89	1409.58	48.92	59.00	138.92	2.23	14.30
371	3.29	19.50	0.79	927.50	9.00	9.00	39.75	0.63	4.42	30.75	0.94	1537.50	50.00	59.00	140.50	2.24	14.69
372	3.26	19.00	0.78	886.67	9.00	8.50	40.92	0.66	4.81	32.42	0.97	1668.34	48.17	57.25	140.08	2.29	15.13
373	3.18	20.17	0.77	881.67	8.92	8.67	38.08	0.63	4.39	29.42	0.93	1494.58	52.50	64.58	152.92	2.32	14.88
374	3.42	20.13	0.81	964.69	8.81	8.56	41.06	0.65	4.80	32.50	0.97	1648.75	49.50	59.00	143.44	2.29	15.20
375	2.81	16.25	0.70	765.00	9.75	10.00	37.75	0.58	3.78	27.75	0.86	1363.75	50.00	61.00	133.75	2.07	13.30
376	2.90	16.58	0.72	773.75	9.33	9.33	38.17	0.61	4.09	28.83	0.90	1441.67	48.33	59.08	132.42	2.10	13.69
377	3.30	19.00	0.79	902.50	8.70	9.00	40.00	0.63	4.44	31.00	0.94	1521.50	48.85	57.80	139.10	2.26	14.78
378	3.32	19.75	0.80	940.00	9.38	9.25	39.00	0.62	4.22	29.75	0.92	1499.38	50.50	60.50	148.63	2.38	15.12
379	3.04	17.67	0.75	831.87	8.96	9.29	38.38	0.61	4.13	29.08	0.91	1422.50	50.08	61.25	140.50	2.19	14.13
380	3.42	20.00	0.81	922.81	8.63	9.31	41.69	0.63	4.48	32.38	0.94	1553.44	45.06	54.25	144.19	2.54	16.00
381	2.80	16.88	0.70	760.63	9.13	9.75	38.25	0.59	3.92	28.50	0.88	1365.63	50.63	63.13	138.25	2.07	13.42
382	2.65	17.75	0.67	697.50	9.25	9.75	38.25	0.59	3.92	28.50	0.88	1377.50	56.00	70.75	157.25	2.18	13.75
491	4.63	24.83	0.96	1162.51	7.75	8.00	41.00	0.67	5.13	33.00	1.00	1626.25	39.17	51.17	141.83	2.55	17.36
492	3.00	17.00	0.74	755.00	9.25	9.50	38.50	0.60	4.05	29.00	0.90	1426.25	47.25	58.00	135.00	2.20	14.10
494	2.81	16.50	0.70	741.88	9.00	9.50	37.00	0.59	3.89	27.50	0.88	1327.50	48.50	61.50	136.00	2.10	13.51
495	2.99	17.04	0.74	780.54	9.18	9.57	37.75	0.60	3.94	28.18	0.88	1371.61	48.79	60.43	134.14	2.10	13.62
496	3.03	17.25	0.74	803.13	9.13	8.75	38.38	0.63	4.39	29.63	0.93	1516.88	47.00	57.38	134.13	2.20	14.35
497	3.09	17.25	0.76	815.00	9.00	8.50	38.50	0.64	4.53	30.00	0.95	1547.50	45.75	55.00	132.25	2.26	14.70
548	7.73	31.13	1.14	1675.00	7.63	8.25	36.38	0.63	4.41	28.13	0.93	1346.88	43.50	50.25	152.63	2.81	20.79
549	6.43	31.25	1.08	1586.25	9.00	9.75	32.00	0.53	3.28	22.25	0.79	1041.25					
550	6.15	29.63	1.07	1528.75	8.00	8.25	38.38	0.65	4.65	30.13	0.96	1482.50	46.75	53.25	154.50	2.70	19.08
551	6.93	30.38	1.11	1601.88	7.88	6.63	42.75	0.73	6.45	36.13	1.09	1925.00	47.13	50.38	157.13	2.80	21.57
552	6.24	27.50	1.07	1470.00	7.75	6.75	41.75	0.72	6.19	35.00	1.07	1845.00					
553	6.30	30.50	1.08	1572.50	9.00	11.00	31.50	0.48	2.86	20.50	0.72	835.00	48.25	56.00	153.25	2.63	17.86
554	7.35	31.75	1.13	1658.75	8.50	7.75	39.50	0.67	5.10	31.75	1.00	1658.75					
555	5.31	26.38	1.01	1342.50	7.88	7.00	42.13	0.72	6.02	35.13	1.06	1839.38	46.88	51.25	148.75	2.64	19.05
556	7.02	31.08	1.11	1641.25	7.75	8.42	35.92	0.62	4.27	27.50	0.92	1311.67	45.08	52.42	155.25	2.76	19.89
557	8.05	33.50	1.16	1770.00	7.75	7.50	40.50	0.69	5.40	33.00	1.02	1673.75	42.75	49.25	160.00	2.90	22.23
558	6.09	29.25	1.06	1510.00	8.00	7.25	40.50	0.70	5.59	33.25	1.03	1733.75					
559	7.29	30.92	1.12	1664.58	7.75	6.75	43.42	0.73	6.43	36.67	1.09	1928.34	47.42	50.67	159.67	2.83	21.94
560	6.17	29.75	1.07	1511.25	9.50	10.75	31.25	0.49	2.91	20.50	0.72	906.25	47.75	55.75	152.75	2.64	17.86
561	6.17	29.75	1.07	1523.13	9.13	10.38	32.50	0.52	3.13	22.13	0.77	987.50	47.88	55.13	155.25	2.70	18.23

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
562	5.94	29.25	1.06	1490.21	7.88	6.92	42.21	0.72	6.10	35.29	1.07	1855.62	46.54	51.58	155.46	2.73	20.07
563	6.58	30.25	1.09	1575.84	9.00	9.92	33.33	0.54	3.36	23.42	0.80	1083.74	48.00	53.58	154.33	2.75	18.94
564	5.69	27.33	1.04	1398.34	9.08	10.08	32.92	0.53	3.26	22.83	0.79	1046.67	48.00	53.92	161.00	2.86	19.07
565	7.08	30.42	1.12	1623.75	7.75	6.75	42.83	0.73	6.35	36.08	1.08	1899.16	46.25	49.58	157.58	2.84	21.76
566	7.25	31.25	1.12	1657.50	7.50	7.25	41.50	0.70	5.72	34.25	1.04	1736.25	45.00	49.50	154.63	2.81	21.26
567	6.98	30.92	1.11	1640.83	8.50	8.58	36.33	0.62	4.23	27.75	0.92	1379.58					
568	5.11	27.15	1.00	1333.75	8.05	6.95	42.15	0.72	6.06	35.20	1.06	1864.50	47.95	53.35	155.25	2.67	19.14
575	3.62	21.25	0.84	967.50	8.00	9.25	34.13	0.57	3.69	24.88	0.85	1125.00	42.75	57.38	140.00	2.39	14.93
15	7.45	32.44	1.13	1767.34	9.14	7.97	45.97	0.70	5.77	38.00	1.05	2011.33	45.69	49.73	156.64	2.75	21.11
16	7.94	35.00	1.15	1886.03	9.18	7.57	48.43	0.73	6.40	40.86	1.08	2196.48	45.48	48.43	161.43	2.82	22.41
17	9.96	38.10	1.21	2080.75	9.35	8.20	50.30	0.72	6.13	42.10	1.07	2214.25	43.55	42.95	175.75	3.30	27.34
18	7.26	32.06	1.12	1739.69	9.13	8.19	46.50	0.70	5.68	38.31	1.04	2004.69	45.50	50.50	156.56	2.72	20.70
19	7.08	31.92	1.12	1698.75	9.25	8.17	45.58	0.70	5.58	37.42	1.03	1973.74	45.25	49.58	153.58	2.71	20.40
226	7.90	34.50	1.15	1867.50	9.25	7.75	47.25	0.72	6.10	39.50	1.07	2117.50	45.00	48.25	157.00	2.76	21.83
227	7.83	34.17	1.15	1850.84	9.17	7.50	47.25	0.73	6.30	39.75	1.08	2145.83	44.83	47.58	160.17	2.87	22.46
228	7.95	34.75	1.15	1868.13	9.25	8.25	46.63	0.70	5.65	38.38	1.04	2013.75	44.38	49.00	159.75	2.80	21.72
229	2.65	14.63	0.67	624.38	11.63	13.63	31.13	0.39	2.28	17.50	0.58	685.00	48.50	60.13	124.50	2.04	12.37
230	7.78	33.88	1.15	1860.00	9.00	8.25	46.75	0.70	5.67	38.50	1.04	1996.25	46.13	49.00	161.25	2.86	21.84
231	5.28	26.75	1.01	1456.25	9.50	8.75	40.75	0.65	4.66	32.00	0.96	1671.25	47.75	54.00	148.00	2.55	17.49
232	7.53	33.88	1.14	1836.25	9.19	8.06	46.44	0.70	5.76	38.38	1.05	2025.63	46.69	50.44	158.94	2.74	21.10
233	6.71	30.92	1.10	1648.74	9.25	8.33	46.42	0.70	5.57	38.08	1.03	1991.26	45.17	51.42	154.17	2.64	19.77
234	8.00	35.00	1.15	1928.13	9.25	7.50	48.63	0.73	6.48	41.13	1.09	2222.50	45.75	49.25	160.38	2.76	22.20
235	7.00	31.50	1.11	1693.75	9.50	8.25	45.75	0.69	5.55	37.50	1.03	1993.75	45.50	50.75	156.50	2.73	20.42
236	3.66	20.63	0.84	1066.88	10.50	11.63	35.63	0.51	3.06	24.00	0.75	1093.13	49.50	58.75	139.50	2.31	14.33
572	2.38	12.38	0.60	500.00	10.25	11.38	28.00	0.42	2.46	16.63	0.63	724.38	49.75	60.88	116.75	1.82	11.46
573	4.66	24.08	0.96	1267.51	9.33	9.08	38.50	0.62	4.24	29.42	0.92	1494.58	47.58	54.42	134.33	2.26	15.58
574	7.24	32.00	1.12	1730.63	9.00	8.13	44.13	0.69	5.43	36.00	1.02	1883.13	44.88	50.00	154.63	2.74	20.61
1	5.40	20.70	1.01	1063.50	9.30	11.35	20.10	0.28	1.77	8.75	0.41	242.75					
2	5.03	18.46	0.98	926.88	9.50	11.38	19.54	0.26	1.72	8.17	0.39	230.21					
3	5.19	20.94	1.00	1040.94	9.00	10.75	20.13	0.30	1.87	9.38	0.45	302.50					
4	4.85	19.25	0.97	938.75	9.00	11.00	19.50	0.28	1.77	8.50	0.41	235.00					
5	3.61	17.17	0.84	779.17	9.25	11.58	21.33	0.30	1.84	9.75	0.44	265.83					
6	4.60	18.00	0.95	860.42	9.50	11.83	19.83	0.25	1.68	8.00	0.37	178.33					
7	4.92	19.25	0.98	946.67	9.25	10.83	19.33	0.28	1.78	8.50	0.42	274.58					
8	5.42	21.00	1.02	1026.25	9.00	11.17	19.42	0.27	1.74	8.25	0.40	206.67					
9	5.04	19.19	0.99	953.44	8.94	11.25	18.88	0.25	1.68	7.63	0.37	161.56	33.63	36.50	169.81	3.68	36.15
10	4.96	18.81	0.98	940.63	8.94	10.94	18.50	0.26	1.69	7.56	0.38	188.13	33.38	34.81	163.31	3.72	37.43
11	4.57	18.75	0.95	913.75	8.63	11.63	19.38	0.25	1.67	7.75	0.37	102.50	35.00	39.50	164.00	3.51	30.59
12	5.15	21.00	1.00	1044.06	9.25	11.00	19.50	0.28	1.77	8.50	0.41	258.75					
13	4.84	19.36	0.97	984.82	9.11	11.00	19.46	0.28	1.77	8.46	0.41	243.39					
14	4.70	18.50	0.96	925.00	9.50	11.13	19.25	0.27	1.73	8.13	0.39	251.88	35.88	36.38	170.00	3.69	35.21
44	8.07	25.10	1.15	1307.25	7.75	9.90	21.60	0.37	2.18	11.70	0.55	380.75	31.25	32.85	161.40	3.79	37.19
45	10.55	31.71	1.22	1694.29	8.14	9.79	22.75	0.40	2.32	12.96	0.59	492.14	31.46	30.75	194.14	4.08	48.55
46	13.82	32.96	1.28	1746.61	7.07	8.54	22.64	0.45	2.65	14.11	0.67	566.25	29.00	29.86	184.36	4.06	50.15
47	12.28	29.90	1.26	1604.25	7.85	10.75	22.10	0.35	2.06	11.35	0.51	292.00					
48	9.97	27.67	1.21	1454.58	8.17	11.00	23.83	0.37	2.17	12.83	0.54	372.50					
49	9.19	27.29	1.19	1451.67	7.54	9.17	21.50	0.40	2.35	12.33	0.59	462.29					
50	11.70	29.44	1.25	1596.56	7.38	9.06	21.00	0.40	2.32	11.94	0.59	436.56					

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
51	8.02	25.17	1.15	1297.92	7.92	10.00	21.83	0.37	2.18	11.83	0.55	393.75	30.08	32.42	173.50	3.92	41.96
52	8.28	26.38	1.16	1378.13	7.25	9.50	21.25	0.38	2.24	11.75	0.56	373.75					
53	9.32	29.13	1.19	1527.50	7.75	9.25	22.50	0.42	2.43	13.25	0.62	520.00					
54	7.77	25.38	1.14	1316.25	8.00	9.75	21.75	0.38	2.23	12.00	0.56	433.75					
55	8.16	25.67	1.16	1307.08	7.58	9.33	20.08	0.37	2.15	10.75	0.54	371.25	29.58	31.33	175.58	3.97	42.46
56	6.02	23.42	1.06	1178.74	7.75	10.58	20.42	0.32	1.93	9.83	0.47	222.50	31.58	37.58	171.00	3.66	30.79
57	10.74	30.44	1.23	1610.94	7.44	9.00	21.56	0.41	2.40	12.56	0.61	479.69	31.19	31.75	186.00	3.97	46.86
58	10.39	28.17	1.22	1479.59	7.17	8.83	22.08	0.43	2.50	13.25	0.63	504.17					
59	10.20	28.75	1.21	1490.94	7.25	8.88	22.13	0.43	2.49	13.25	0.63	508.13					
60	7.86	24.88	1.14	1279.38	7.50	9.75	21.00	0.37	2.15	11.25	0.54	348.75	29.88	32.25	174.88	3.93	41.65
61	8.11	26.08	1.15	1335.83	7.58	9.67	20.83	0.37	2.16	11.17	0.54	360.41	29.83	32.33	175.33	3.91	40.47
72	7.46	22.95	1.13	1204.50	7.70	9.30	18.15	0.32	1.95	8.85	0.47	290.50					
73	5.67	20.13	1.03	1018.13	8.00	9.63	19.00	0.33	1.97	9.38	0.48	314.38					
74	6.96	23.33	1.11	1198.33	8.08	9.50	18.92	0.33	1.99	9.42	0.49	336.25					
75	6.54	21.25	1.08	1102.08	7.92	9.42	19.25	0.34	2.04	9.83	0.51	349.17	30.42	29.42	161.50	4.02	41.80
76	5.71	20.00	1.03	1023.75	9.00	10.75	19.75	0.30	1.84	9.00	0.44	283.75	34.25	36.25	161.25	3.72	31.98
77	6.84	22.63	1.10	1166.88	7.75	9.50	18.50	0.32	1.95	9.00	0.47	283.75	29.25	28.00	188.38	4.19	53.17
78	5.85	20.00	1.04	1023.75	7.13	8.00	16.38	0.34	2.05	8.38	0.51	335.63	30.00	27.88	157.00	3.99	40.81
79	5.95	20.05	1.05	1045.25	8.60	10.75	18.75	0.27	1.74	8.00	0.40	195.75	31.35	31.60	156.90	3.84	38.16
80	5.17	18.50	1.00	948.75	8.44	10.25	17.50	0.26	1.71	7.25	0.38	190.31	31.56	32.00	150.63	3.75	34.89
81	6.32	20.63	1.07	1066.88	7.75	10.13	17.25	0.26	1.70	7.13	0.38	130.63	28.25	29.25	160.88	3.97	44.80
82	8.23	23.50	1.16	1246.25	8.00	9.50	18.75	0.33	1.97	9.25	0.48	320.00	28.00	27.50	174.00	4.20	50.86
83	7.33	22.17	1.12	1155.84	7.83	9.42	16.75	0.28	1.78	7.33	0.41	216.25	28.00	26.83	168.33	4.16	49.60
84	8.71	23.13	1.17	1251.25	7.75	9.50	17.50	0.30	1.84	8.00	0.44	233.75	27.88	26.38	169.00	4.21	51.07
85	5.76	19.25	1.04	982.29	8.33	10.54	18.92	0.28	1.79	8.38	0.42	208.96	30.63	32.00	156.83	3.83	37.52
86	6.23	20.92	1.07	1085.42	8.33	10.00	19.00	0.31	1.90	9.00	0.46	291.67	31.00	30.58	168.50	3.98	42.64
87	6.93	22.25	1.10	1183.75	8.00	9.25	18.38	0.33	1.99	9.13	0.49	337.50	30.25	28.38	170.75	4.12	47.16
88	7.29	21.50	1.12	1106.67	7.83	9.92	17.58	0.28	1.77	7.67	0.41	185.41	27.33	27.50	166.00	4.14	49.48
89	5.88	19.50	1.04	975.00	7.75	9.63	16.75	0.27	1.74	7.13	0.40	178.13	28.13	29.75	153.50	3.93	37.08
90	7.00	21.00	1.11	1121.25	8.00	9.25	19.00	0.35	2.05	9.75	0.51	368.75	30.00	28.00	164.75	4.12	45.49
91	4.54	18.56	0.94	880.63	9.56	12.06	19.31	0.23	1.60	7.25	0.34	125.00	33.94	37.50	159.56	3.60	33.76
92	5.09	19.75	0.99	1003.33	9.67	11.92	20.00	0.25	1.68	8.08	0.37	190.42					
93	4.16	19.75	0.90	868.75	9.75	12.25	19.50	0.23	1.59	7.25	0.34	125.00					
94	4.95	19.75	0.98	963.75	9.00	12.25	19.25	0.22	1.57	7.00	0.33	41.25	32.75	34.75	166.00	3.75	41.14
95	5.50	20.25	1.02	1012.50	9.75	12.25	19.50	0.23	1.59	7.25	0.34	125.00					
96	4.88	19.38	0.97	968.75	9.75	11.38	21.50	0.31	1.89	10.13	0.46	351.88					
97	3.96	17.75	0.88	768.75	8.25	9.50	22.25	0.40	2.34	12.75	0.59	518.75					
117	5.53	21.50	1.02	1027.50	9.50	11.38	19.50	0.26	1.71	8.13	0.39	228.13					
118	5.89	22.00	1.05	1100.00	9.00	10.75	19.75	0.30	1.84	9.00	0.44	283.75	37.00	37.00	180.75	3.76	38.24
119	4.04	19.38	0.89	921.25	9.50	11.50	19.38	0.26	1.68	7.88	0.38	203.75	35.38	38.00	179.00	3.68	37.61
121	5.68	22.25	1.03	1088.75	9.50	11.25	20.25	0.29	1.80	9.00	0.42	283.75					
122	5.69	21.13	1.03	1056.25	9.25	11.25	19.13	0.26	1.70	7.88	0.38	203.75	35.13	35.63	178.25	3.83	40.94
123	5.89	22.00	1.05	1123.75	9.50	11.25	19.25	0.26	1.71	8.00	0.39	233.75	33.75	34.75	180.50	3.85	44.26
124	6.29	22.50	1.07	1148.75	9.25	11.00	20.00	0.29	1.82	9.00	0.43	283.75					
125	6.81	22.50	1.10	1160.63	8.63	11.63	21.50	0.30	1.85	9.88	0.44	208.75	35.75	39.13	151.00	3.38	27.02
126	6.48	21.92	1.08	1111.67	8.42	10.58	20.58	0.32	1.94	10.00	0.47	294.17					
127	6.76	23.75	1.10	1199.38	8.38	10.50	20.50	0.32	1.95	10.00	0.48	298.13	35.75	38.13	159.50	3.48	28.91
128	7.86	24.58	1.14	1292.51	8.25	11.08	20.75	0.30	1.87	9.67	0.45	214.17	35.08	38.42	152.25	3.40	28.41

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
129	7.76	24.50	1.14	1284.38	8.25	11.00	21.25	0.32	1.93	10.25	0.47	251.25					
130	7.93	25.13	1.15	1291.88	8.19	10.88	22.06	0.34	2.03	11.19	0.50	304.06					
131	6.60	22.42	1.09	1144.59	8.50	10.92	20.42	0.30	1.87	9.50	0.45	245.42					
132	7.13	24.50	1.11	1248.75	8.00	10.75	22.25	0.35	2.07	11.50	0.51	313.75	35.25	39.50	150.25	3.34	26.57
133	6.75	23.30	1.10	1184.00	8.55	10.50	21.80	0.35	2.08	11.30	0.52	379.75	36.45	38.50	152.55	3.42	27.33
134	6.74	23.31	1.09	1177.50	8.25	10.56	21.25	0.34	2.01	10.69	0.50	314.69	35.06	38.19	160.13	3.51	29.05
135	6.19	23.33	1.07	1166.66	8.00	10.75	20.17	0.30	1.88	9.42	0.45	209.58	35.50	39.00	162.75	3.47	28.16
136	6.18	22.00	1.06	1100.00	8.42	10.58	21.42	0.34	2.02	10.83	0.50	335.84	36.42	39.92	149.67	3.32	25.73
137	7.40	24.00	1.13	1223.75	7.63	10.25	21.75	0.36	2.12	11.50	0.53	325.63	32.88	35.88	154.50	3.57	30.62
138	6.03	22.00	1.06	1088.13	8.38	10.25	21.75	0.36	2.12	11.50	0.53	396.88	35.38	39.00	151.25	3.40	25.84
139	10.38	31.06	1.22	1618.44	7.94	10.25	22.50	0.37	2.20	12.25	0.55	392.81	35.00	36.81	175.00	3.69	35.91
140	6.91	22.67	1.10	1196.67	9.08	11.08	21.00	0.31	1.89	9.92	0.46	305.83	35.75	38.17	149.50	3.39	27.50
141	6.78	24.00	1.10	1223.75	8.45	10.70	20.75	0.32	1.94	10.05	0.47	288.75	35.60	38.70	158.15	3.46	28.02
142	7.77	24.83	1.14	1305.00	8.25	11.00	21.17	0.32	1.92	10.17	0.47	247.08					
143	8.89	27.63	1.18	1452.50	7.75	9.00	22.50	0.43	2.50	13.50	0.63	556.25	34.13	35.88	154.38	3.54	30.46
160	5.50	20.25	1.02	1036.25	8.75	11.00	19.00	0.27	1.73	8.00	0.39	186.25	30.50	32.50	159.00	3.82	42.04
161	6.25	21.00	1.07	1097.50	9.00	12.00	20.00	0.25	1.67	8.00	0.37	115.00	33.25	34.25	174.50	3.89	43.55
162	6.03	22.00	1.06	1123.75	9.50	11.25	19.50	0.27	1.73	8.25	0.40	246.25	34.00	34.75	180.38	3.86	42.69
163	6.30	22.08	1.07	1120.00	9.17	11.17	19.58	0.27	1.75	8.42	0.40	230.83	33.92	34.67	178.25	3.86	42.59
164	5.94	22.25	1.05	1112.50	9.25	10.75	19.25	0.28	1.79	8.50	0.42	282.50	34.25	33.00	178.00	3.93	43.96
165	5.59	19.50	1.03	1010.63	8.75	11.00	19.00	0.27	1.73	8.00	0.39	186.25	31.25	32.88	158.63	3.79	39.55
166	5.35	20.13	1.01	1006.25	9.00	11.00	19.00	0.27	1.73	8.00	0.39	210.00	32.75	34.25	168.25	3.80	40.91
167	5.69	20.65	1.03	1042.00	9.15	11.20	19.25	0.26	1.72	8.05	0.39	207.75	33.15	34.70	175.20	3.84	40.55
168	5.74	20.13	1.04	1018.13	9.38	11.00	19.25	0.27	1.75	8.25	0.40	258.13	32.88	32.88	175.13	3.89	46.16
169	5.72	21.25	1.04	1038.75	8.75	11.13	19.25	0.27	1.73	8.13	0.39	180.63	31.13	32.38	172.38	3.91	46.03
198	4.80	19.00	0.97	926.25	9.75	11.25	20.00	0.28	1.78	8.75	0.41	295.00					
200	4.60	18.00	0.95	876.25	9.75	12.25	20.00	0.24	1.63	7.75	0.35	150.00					
201	3.58	17.75	0.83	756.88	8.88	10.75	19.25	0.28	1.79	8.50	0.42	246.88					
202	5.24	19.63	1.00	981.25	9.63	11.88	20.25	0.26	1.71	8.38	0.39	205.00					
203	6.06	22.75	1.06	1161.25	8.75	11.00	20.00	0.29	1.82	9.00	0.43	236.25					
205	5.00	20.00	0.98	976.25	8.75	10.75	20.00	0.30	1.86	9.25	0.44	272.50					
206	5.72	21.25	1.04	1050.63	8.25	10.63	19.88	0.30	1.87	9.25	0.45	236.88					
207	5.47	21.25	1.02	1062.50	9.25	10.75	19.50	0.29	1.81	8.75	0.43	295.00					
208	5.26	20.25	1.00	1024.38	9.25	11.25	19.63	0.27	1.74	8.38	0.40	228.75					
209	5.62	22.50	1.03	1101.25	9.25	11.25	19.25	0.26	1.71	8.00	0.39	210.00					
210	5.34	20.63	1.01	1031.25	9.00	10.63	19.50	0.29	1.84	8.88	0.43	289.38					
211	4.76	19.75	0.96	940.00	9.00	10.75	19.25	0.28	1.79	8.50	0.42	258.75					
212	4.90	19.50	0.98	998.75	9.13	11.25	19.75	0.27	1.76	8.50	0.40	223.13					
213	4.54	20.08	0.94	940.83	8.92	11.25	19.25	0.26	1.71	8.00	0.39	178.33					
214	4.90	19.50	0.98	951.25	9.25	11.00	19.00	0.27	1.73	8.00	0.39	233.75	36.25	36.25	172.38	3.71	36.16
215	5.16	19.75	1.00	1023.13	9.00	11.13	19.13	0.26	1.72	8.00	0.39	198.13	35.00	36.19	170.94	3.71	36.03
216	4.85	19.25	0.97	962.50	9.25	11.00	19.25	0.27	1.75	8.25	0.40	246.25	35.25	36.50	178.75	3.76	36.28
217	4.98	19.88	0.98	958.13	9.25	10.75	19.38	0.29	1.80	8.63	0.42	288.75					
218	5.12	19.92	0.99	980.00	9.08	10.75	18.58	0.27	1.73	7.83	0.39	233.33	33.75	35.25	171.42	3.74	37.69
219	5.38	20.08	1.01	1012.09	9.08	11.50	19.42	0.26	1.69	7.92	0.38	166.25					
220	5.03	20.13	0.99	982.50	9.25	11.50	19.38	0.26	1.68	7.88	0.38	180.00					
271	9.54	27.75	1.20	1482.50	7.50	8.75	22.25	0.44	2.54	13.50	0.64	556.25					
272	10.25	27.75	1.22	1435.00	7.08	8.92	21.25	0.41	2.38	12.33	0.60	442.50					

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
273	13.28	32.75	1.27	1764.17	7.42	9.00	22.58	0.43	2.51	13.58	0.64	528.75	30.25	31.50	177.08	3.93	46.53
274	13.73	31.83	1.28	1686.66	7.08	8.17	22.75	0.47	2.79	14.58	0.70	626.25	29.00	29.08	179.25	4.07	49.95
275	8.04	33.00	1.15	1697.50	7.88	10.63	23.88	0.38	2.25	13.25	0.57	401.25	32.19	36.06	188.13	3.87	37.69
276	11.20	28.06	1.24	1527.81	7.63	9.44	22.06	0.40	2.34	12.63	0.59	459.06	30.69	30.88	181.38	4.00	47.35
277	8.60	26.58	1.17	1400.41	7.92	9.58	21.67	0.39	2.26	12.08	0.57	445.84					
278	8.09	25.25	1.15	1327.81	8.00	9.31	21.63	0.40	2.32	12.31	0.59	490.94	32.56	33.19	169.00	3.83	38.47
279	7.55	25.38	1.13	1292.50	7.75	9.75	21.00	0.37	2.15	11.25	0.54	372.50	30.13	31.75	171.13	3.91	40.91
280	8.57	26.50	1.17	1372.50	7.75	9.75	22.13	0.39	2.27	12.38	0.57	428.75	29.63	30.75	174.25	4.00	43.46
281	8.16	26.25	1.16	1375.84	7.58	9.58	21.83	0.39	2.28	12.25	0.58	422.50					
282	10.56	28.69	1.22	1499.69	7.00	8.88	21.88	0.42	2.46	13.00	0.62	471.88					
283	7.60	24.75	1.13	1261.25	7.75	9.75	21.50	0.38	2.21	11.75	0.56	397.50	30.00	31.50	175.75	3.97	43.91
284	11.70	29.42	1.25	1589.59	7.33	9.33	21.67	0.40	2.32	12.33	0.59	426.67					
285	10.17	27.50	1.21	1410.63	7.63	9.50	22.13	0.40	2.33	12.63	0.59	453.13					
286	11.45	28.75	1.24	1556.25	7.58	9.25	20.83	0.39	2.25	11.58	0.57	420.83					
287	8.39	25.88	1.16	1365.00	7.75	9.13	21.00	0.39	2.30	11.88	0.58	463.13	31.50	33.00	168.63	3.81	37.81
288	11.00	30.50	1.23	1610.50	7.50	9.15	22.25	0.42	2.43	13.10	0.62	498.25	30.65	30.80	189.05	4.04	49.15
289	5.70	23.50	1.04	1175.00	7.75	10.50	21.25	0.34	2.02	10.75	0.50	276.25	32.75	37.75	179.75	3.72	32.31
290	10.55	26.25	1.22	1455.00	7.75	9.25	21.75	0.40	2.35	12.50	0.60	482.50	31.00	32.75	166.75	3.80	39.41
291	9.65	28.13	1.20	1501.25	7.50	9.25	21.38	0.40	2.31	12.13	0.58	440.00					
292	12.27	31.00	1.26	1692.50	7.25	9.25	22.25	0.41	2.41	13.00	0.61	460.00	31.25	31.50	186.75	3.99	47.95
293	9.32	26.00	1.19	1359.38	7.75	9.25	21.00	0.39	2.27	11.75	0.57	445.00					
294	8.07	25.63	1.15	1316.88	7.75	9.50	20.50	0.37	2.16	11.00	0.54	383.75	30.13	31.38	174.63	3.96	42.35
295	7.73	25.25	1.14	1310.00	7.75	9.50	21.50	0.39	2.26	12.00	0.57	433.75	31.75	34.00	167.50	3.77	36.54
296	12.73	32.25	1.26	1755.00	7.00	8.00	22.50	0.48	2.81	14.50	0.70	630.00	28.75	29.50	187.25	4.13	51.07
297	8.17	26.00	1.16	1359.38	7.63	9.38	21.88	0.40	2.33	12.50	0.59	458.75	31.75	33.88	168.88	3.79	37.07
298	8.43	26.00	1.16	1371.25	8.00	9.75	21.50	0.38	2.21	11.75	0.56	421.25	32.50	33.50	166.50	3.81	36.64
299	12.44	30.50	1.26	1675.42	7.42	8.83	21.75	0.42	2.46	12.92	0.62	511.25	30.75	30.00	182.58	4.02	49.55
317	7.23	23.38	1.12	1204.38	7.81	9.31	18.25	0.32	1.96	8.94	0.48	304.38					
318	6.00	21.25	1.05	1062.50	7.75	9.25	18.50	0.33	2.00	9.25	0.49	320.00					
319	8.59	25.63	1.17	1382.19	7.63	9.13	17.75	0.32	1.95	8.63	0.47	288.75	29.75	26.81	187.19	4.22	55.54
320	6.53	22.13	1.08	1153.75	7.50	9.50	18.75	0.33	1.97	9.25	0.48	272.50	29.50	29.25	169.13	4.09	43.53
321	5.84	20.25	1.04	1048.13	8.19	10.00	19.63	0.32	1.96	9.63	0.48	309.06	32.06	32.25	155.00	3.81	35.16
322	6.85	23.42	1.10	1194.59	8.17	10.33	19.83	0.31	1.92	9.50	0.46	269.17	30.00	28.75	167.17	4.15	45.10
323	6.28	21.13	1.07	1080.00	8.50	10.00	17.25	0.27	1.73	7.25	0.39	220.00	30.25	30.88	163.13	3.93	40.19
324	6.49	20.94	1.08	1088.44	8.19	9.75	17.50	0.28	1.79	7.75	0.42	239.06	29.63	29.56	161.13	3.97	42.89
325	6.39	20.88	1.08	1091.25	8.13	9.50	18.13	0.31	1.91	8.63	0.46	300.63	30.25	28.63	161.25	4.03	44.78
326	6.78	21.67	1.10	1107.09	7.58	9.67	17.58	0.29	1.82	7.92	0.43	197.91	28.25	29.25	164.08	4.00	44.04
327	6.90	21.87	1.10	1129.37	7.67	8.75	18.46	0.36	2.11	9.71	0.53	382.50	29.96	28.83	169.92	4.08	45.50
328	7.59	22.50	1.13	1180.42	8.42	10.92	18.58	0.26	1.70	7.67	0.38	145.83	28.58	28.58	167.33	4.08	49.53
329	8.30	24.63	1.16	1290.63	7.69	9.56	18.13	0.31	1.90	8.56	0.46	250.00	28.19	27.13	180.56	4.21	54.19
330	6.81	21.54	1.10	1144.38	7.92	9.50	19.13	0.34	2.01	9.63	0.50	330.83	30.50	29.83	165.62	4.05	42.60
331	6.29	20.81	1.07	1052.50	8.25	9.94	18.69	0.31	1.88	8.75	0.45	277.19	29.25	30.31	158.94	3.93	40.59
332	5.63	18.50	1.03	948.75	7.75	9.25	17.00	0.30	1.84	7.75	0.43	245.00	29.25	28.88	153.25	3.97	39.34
333	5.77	18.50	1.04	960.63	7.38	9.25	16.75	0.29	1.81	7.50	0.42	196.88	29.13	28.88	153.13	3.95	39.24
334	5.21	20.00	1.00	952.50	8.00	10.13	17.75	0.27	1.75	7.63	0.40	179.38	29.00	32.75	160.75	3.84	34.55
335	7.50	22.75	1.13	1137.50	8.00	11.00	20.25	0.30	1.84	9.25	0.44	177.50	27.50	28.25	168.25	4.16	49.98
336	7.71	23.15	1.14	1181.25	7.80	10.10	17.85	0.28	1.77	7.75	0.41	169.00	27.50	27.75	172.20	4.17	50.09
337	7.40	24.00	1.13	1271.25	8.25	9.25	19.75	0.36	2.14	10.50	0.53	430.00	30.25	30.75	162.50	3.97	38.77

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
338	7.53	24.50	1.13	1272.50	7.67	9.33	17.25	0.30	1.85	7.92	0.44	237.50	29.25	27.33	179.83	4.16	51.31
339	5.85	20.00	1.04	1035.63	8.00	10.50	19.00	0.29	1.81	8.50	0.43	187.50	30.88	31.25	147.88	3.84	34.38
340	6.18	22.00	1.06	1123.75	9.00	10.00	19.50	0.32	1.95	9.50	0.48	380.00	31.25	31.75	180.25	4.05	42.14
341	6.25	21.00	1.07	1097.50	8.50	10.50	18.25	0.27	1.74	7.75	0.40	197.50	31.50	31.00	161.25	3.92	41.92
342	4.85	19.25	0.97	891.25	9.50	12.00	19.50	0.24	1.63	7.50	0.35	137.50	33.50	35.25	164.00	3.72	39.21
343	4.54	18.00	0.94	892.08	9.25	11.25	18.42	0.24	1.64	7.17	0.36	168.33	34.33	35.50	168.33	3.71	38.48
344	4.75	18.75	0.96	913.75	9.50	12.25	19.50	0.23	1.59	7.25	0.34	101.25	33.25	36.00	166.00	3.73	38.67
345	5.56	20.50	1.03	1025.00	9.63	11.88	19.38	0.24	1.63	7.50	0.35	161.25					
346	4.94	19.19	0.98	971.25	9.56	11.75	19.56	0.25	1.66	7.81	0.37	182.81					
347	2.53	11.50	0.64	480.00	10.50	13.25	23.00	0.27	1.74	9.75	0.40	226.25	39.00	45.00	135.75	3.06	19.95
348	4.68	18.88	0.96	902.19	9.63	12.25	19.50	0.23	1.59	7.25	0.34	113.13	34.19	36.75	170.38	3.70	39.01
349	3.32	18.58	0.79	778.75	9.00	11.75	18.42	0.22	1.57	6.67	0.33	72.08					
350	5.67	21.00	1.03	1050.00	9.75	12.25	20.50	0.25	1.67	8.25	0.37	175.00					
351	4.89	18.50	0.97	948.75	9.00	11.25	18.25	0.24	1.62	7.00	0.35	136.25	33.25	35.00	164.00	3.68	38.30
352	5.00	19.00	0.98	973.75	9.25	11.25	18.75	0.25	1.67	7.50	0.37	185.00	34.75	35.00	167.75	3.74	38.87
353	4.12	19.50	0.90	903.75	9.75	12.50	19.50	0.22	1.56	7.00	0.32	88.75					
354	3.74	18.50	0.85	830.00	9.50	12.00	19.50	0.24	1.63	7.50	0.35	137.50	33.75	39.75	161.00	3.51	30.82
355	4.33	19.13	0.92	908.75	9.25	11.00	19.25	0.27	1.75	8.25	0.40	246.25					
357	5.60	20.33	1.03	1032.50	9.67	11.50	19.67	0.26	1.71	8.17	0.39	234.17	34.00	35.17	179.58	3.84	40.87
358	4.58	20.13	0.95	1006.25	9.88	12.25	20.63	0.25	1.68	8.38	0.38	193.13					
359	4.67	19.25	0.95	915.00	9.50	12.25	19.50	0.23	1.59	7.25	0.34	101.25	34.50	38.00	173.75	3.66	35.69
383	4.00	19.50	0.89	880.00	9.25	11.25	20.00	0.28	1.78	8.75	0.41	247.50	35.00	38.25	179.50	3.70	36.24
384	5.42	21.00	1.02	1073.75	9.50	11.25	19.25	0.26	1.71	8.00	0.39	233.75	35.00	38.00	178.25	3.73	36.98
385	5.78	21.50	1.04	1098.75	9.50	10.75	19.75	0.30	1.84	9.00	0.44	331.25					
386	5.58	21.75	1.03	1087.50	9.13	11.25	19.50	0.27	1.73	8.25	0.40	210.63					
387	5.47	21.25	1.02	1015.00	9.50	11.25	19.25	0.26	1.71	8.00	0.39	233.75	33.50	34.75	180.00	3.86	43.81
388	6.26	25.00	1.07	1250.00	9.50	11.50	19.50	0.26	1.70	8.00	0.38	210.00	33.25	36.00	188.75	3.87	42.89
389	5.50	21.38	1.02	1033.13	9.25	11.13	19.75	0.28	1.78	8.63	0.41	253.13					
390	5.20	21.00	1.00	1002.50	9.00	11.25	19.25	0.26	1.71	8.00	0.39	186.25	35.00	38.00	183.25	3.75	37.88
391	5.50	21.75	1.02	1063.75	9.25	11.17	19.25	0.27	1.72	8.08	0.39	222.08	34.17	36.08	179.42	3.80	40.35
392	5.72	21.25	1.04	1086.25	9.50	11.25	19.50	0.27	1.73	8.25	0.40	246.25	33.50	34.75	176.75	3.84	42.98
393	5.94	22.25	1.05	1112.50	9.00	11.25	19.25	0.26	1.71	8.00	0.39	186.25	34.00	35.25	182.00	3.84	42.70
394	5.78	21.50	1.04	1086.88	9.25	11.13	19.25	0.27	1.73	8.13	0.39	228.13	35.25	36.38	179.13	3.80	39.60
395	7.75	27.00	1.14	1397.50	9.25	11.00	20.00	0.29	1.82	9.00	0.43	283.75	33.50	35.25	188.00	3.92	43.48
397	7.13	24.50	1.11	1248.75	9.25	11.00	20.00	0.29	1.82	9.00	0.43	283.75	32.75	33.75	195.38	4.01	47.17
398	5.63	22.00	1.03	1076.25	9.25	11.25	19.25	0.26	1.71	8.00	0.39	210.00	34.00	35.75	181.00	3.83	41.81
399	5.44	22.58	1.02	1097.51	9.33	11.50	19.25	0.25	1.67	7.75	0.37	181.67	33.08	36.00	181.17	3.80	40.88
400	3.79	19.50	0.86	880.00	9.38	11.50	18.63	0.24	1.62	7.13	0.35	154.38	35.13	40.63	181.13	3.58	33.18
401	6.87	22.00	1.10	1159.38	8.25	10.88	20.00	0.30	1.84	9.13	0.44	206.88					
402	7.67	25.44	1.14	1301.56	7.81	10.31	20.00	0.32	1.94	9.69	0.47	246.88					
403	7.24	23.92	1.12	1235.42	9.17	11.33	21.50	0.31	1.90	10.17	0.46	302.50	36.25	38.33	150.83	3.41	28.11
404	8.61	26.63	1.17	1402.50	8.63	11.50	23.00	0.33	2.00	11.50	0.49	301.88					
405	6.52	22.75	1.08	1149.38	8.31	10.19	21.63	0.36	2.12	11.44	0.53	393.75	35.50	37.31	153.75	3.49	28.08
406	7.90	25.88	1.15	1341.25	8.25	10.00	21.50	0.37	2.15	11.50	0.54	408.75	35.88	37.88	156.50	3.48	28.96
407	6.14	21.83	1.06	1075.83	8.33	10.17	21.08	0.35	2.07	10.92	0.52	371.66	35.58	38.75	158.58	3.46	27.40
408	8.90	27.67	1.18	1438.75	8.17	10.67	22.33	0.35	2.09	11.67	0.52	345.83	34.25	37.17	168.08	3.63	33.10
409	8.59	27.50	1.17	1410.63	8.13	10.38	22.38	0.37	2.16	12.00	0.54	386.25	35.00	38.38	157.50	3.47	29.69
410	8.75	31.00	1.18	1550.00	7.75	10.00	22.25	0.38	2.23	12.25	0.56	398.75	33.25	36.13	179.75	3.74	36.70

AOI ID	287 RVI	287 DVI	287 SAVI	287 TVI	320-1	320-2	320-3	320NDVI	320 RVI	320 DVI	320 SAVI	320 TVI	Sum Band 1	Sum Band 2	Sum Band3	Sum NDVI	Sum RVI
411	8.29	25.50	1.16	1346.25	8.75	11.00	21.75	0.33	1.98	10.75	0.48	323.75					
412	6.81	23.25	1.10	1186.25	8.75	11.25	20.25	0.29	1.80	9.00	0.42	212.50					
413	6.11	23.42	1.06	1162.92	8.33	10.92	20.58	0.31	1.89	9.67	0.45	237.91					
414	6.91	23.63	1.10	1205.00	8.25	10.63	19.75	0.30	1.86	9.13	0.44	230.63	34.75	36.75	159.63	3.55	30.59
415	6.90	22.13	1.10	1153.75	9.00	11.13	20.75	0.30	1.87	9.63	0.45	279.38	36.63	38.00	152.25	3.43	28.53
416	5.83	22.94	1.04	1135.00	8.00	10.75	20.50	0.31	1.91	9.75	0.46	226.25					
417	5.28	23.17	1.01	1142.49	8.08	10.83	20.33	0.30	1.88	9.50	0.45	213.75					
418	6.82	21.83	1.10	1139.16	8.50	11.08	20.42	0.30	1.84	9.33	0.44	221.25					
419	6.50	22.00	1.08	1111.88	8.50	10.75	20.75	0.32	1.93	10.00	0.47	286.25	35.50	37.75	155.38	3.49	28.27
420	8.63	26.08	1.17	1359.58	7.75	10.33	20.67	0.33	2.00	10.33	0.49	271.25	34.67	36.08	159.42	3.58	31.98
421	7.47	24.25	1.13	1236.25	8.00	10.00	22.25	0.38	2.23	12.25	0.56	422.50	35.13	37.25	147.25	3.42	27.89
423	7.91	24.19	1.14	1286.56	8.88	10.88	22.31	0.34	2.05	11.44	0.51	381.88					
424	8.55	26.05	1.17	1373.75	8.35	11.10	23.35	0.36	2.10	12.25	0.53	351.25					
425	7.86	24.00	1.14	1271.25	8.33	11.08	20.67	0.30	1.86	9.58	0.45	217.92					
426	8.68	28.17	1.17	1439.99	8.08	10.58	23.17	0.37	2.19	12.58	0.55	391.67	35.08	37.25	170.67	3.66	33.52
427	6.60	25.67	1.09	1267.50	7.92	10.17	21.58	0.36	2.12	11.42	0.53	357.08	35.67	39.92	163.75	3.46	27.39
428	7.40	24.00	1.13	1235.63	8.00	10.63	21.75	0.34	2.05	11.13	0.51	306.88	34.88	38.25	147.38	3.36	27.40
429	8.48	26.17	1.17	1371.67	8.17	11.33	22.17	0.32	1.96	10.83	0.48	240.84					
430	6.94	23.75	1.10	1235.00	8.25	11.00	21.00	0.31	1.91	10.00	0.46	238.75	36.00	38.00	154.50	3.44	28.67
431	6.25	22.00	1.07	1111.88	8.88	10.63	21.25	0.33	2.00	10.63	0.49	365.00	37.31	39.88	148.94	3.31	25.74
432	6.94	23.75	1.10	1211.25	8.50	10.50	21.00	0.33	2.00	10.50	0.49	335.00	36.08	37.92	161.08	3.52	29.72
433	5.50	22.50	1.02	1065.63	8.00	10.38	21.38	0.35	2.06	11.00	0.51	324.38	35.63	41.88	159.25	3.33	24.91
446	6.63	22.50	1.09	1148.75	9.50	11.50	19.25	0.25	1.67	7.75	0.37	197.50	33.25	33.50	175.75	3.86	44.17
447	5.05	19.25	0.99	938.75	9.25	11.25	19.25	0.26	1.71	8.00	0.39	210.00	32.50	33.25	162.75	3.79	39.64
448	6.30	22.08	1.07	1112.08	9.25	11.00	19.42	0.28	1.77	8.42	0.41	254.58	32.83	33.58	179.92	3.92	45.30
449	5.50	20.25	1.02	1012.50	9.00	11.25	20.00	0.28	1.78	8.75	0.41	223.75	33.25	34.25	170.50	3.82	39.76
450	5.44	20.00	1.02	1011.88	9.25	11.50	19.50	0.26	1.70	8.00	0.38	186.25	33.38	35.25	171.25	3.80	38.18
451	5.65	19.75	1.03	999.38	9.00	11.63	19.38	0.25	1.67	7.75	0.37	138.13	32.63	34.63	171.25	3.84	39.48
452	6.56	22.25	1.09	1136.25	8.88	11.38	19.50	0.26	1.71	8.13	0.39	168.75	32.63	32.38	181.13	3.99	50.29
453	6.12	21.75	1.06	1087.50	8.88	11.13	19.25	0.27	1.73	8.13	0.39	192.50	31.88	32.13	171.13	3.91	46.55
454	5.75	21.75	1.04	1087.50	9.17	11.00	19.42	0.28	1.77	8.42	0.41	246.67	31.92	33.33	173.00	3.88	42.59
455	6.00	23.75	1.06	1187.50	9.00	11.25	19.00	0.26	1.69	7.75	0.38	173.75	32.75	32.75	167.25	3.87	42.34
456	6.00	21.25	1.05	1062.50	8.75	11.75	19.25	0.24	1.64	7.50	0.36	90.00	30.00	31.75	164.50	3.91	45.88
457	5.59	19.50	1.03	998.75	8.75	11.00	19.00	0.27	1.73	8.00	0.39	186.25	30.00	32.50	157.50	3.82	39.68
594	5.94	21.83	1.05	1099.58	7.83	9.33	20.33	0.37	2.18	11.00	0.55	407.50					
595	4.48	20.00	0.94	905.00	9.25	11.25	19.25	0.26	1.71	8.00	0.39	210.00					

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
62	222.55	6.29	11355.50	36.65	31.80	242.30	3.76	47.15	210.50	5.60	10985.75	26.55
63	143.54	5.02	6911.87	40.63	40.38	177.08	3.07	24.05	136.71	4.55	6859.16	31.25
64	201.36	6.08	10247.68	37.57	33.29	223.57	3.64	41.79	190.29	5.41	9921.43	27.11
65	203.94	6.06	10357.19	37.56	33.50	226.63	3.64	40.87	193.13	5.40	10042.19	27.19
66	138.95	5.05	6686.25	39.75	39.30	171.25	3.08	23.82	131.95	4.57	6640.25	30.05
67	202.55	6.08	10331.75	37.80	33.20	225.00	3.65	41.54	191.80	5.43	10027.00	27.30
68	218.25	6.21	11019.38	37.13	33.75	239.00	3.69	42.35	205.25	5.48	10583.13	27.00
69	206.75	6.08	10485.94	37.50	33.56	229.13	3.65	42.55	195.56	5.42	10152.19	27.00
70	201.19	6.00	10190.00	37.19	33.50	224.06	3.60	41.57	190.56	5.34	9878.44	27.00
71	197.79	6.02	10040.00	37.62	33.54	220.92	3.62	40.13	187.38	5.38	9756.67	27.17
107	194.50	5.86	9867.50	39.50	35.25	218.75	3.53	40.05	183.50	5.24	9578.75	28.25
108												
109	207.88	5.91	10346.25	38.25	36.38	234.63	3.56	40.50	198.25	5.29	10090.63	27.50
110	219.88	6.17	11338.13	40.38	35.00	242.13	3.65	45.65	207.13	5.42	10866.88	29.25
111	215.88	6.10	11031.25	39.13	35.00	239.00	3.62	45.50	204.00	5.38	10591.88	28.13
112	209.75	6.07	10772.50	39.38	34.63	230.88	3.57	42.68	196.25	5.31	10263.75	28.50
113	188.50	5.66	9430.00	39.75	35.25	215.25	3.50	38.88	180.00	5.20	9427.50	28.50
114	193.63	5.79	9681.25	38.50	35.88	220.13	3.52	38.98	184.25	5.23	9461.88	27.75
115												
144	196.00	5.92	10061.25	39.50	34.50	219.25	3.53	41.58	184.75	5.25	9712.50	29.00
145	196.50	5.96	10074.38	38.63	33.75	219.38	3.56	41.87	185.63	5.29	9744.38	28.13
146												
147	196.00	5.92	10029.59	39.50	34.92	221.25	3.56	40.10	186.33	5.29	9752.09	28.83
148	185.13	5.65	9161.25	39.13	36.88	212.25	3.43	34.29	175.38	5.09	8982.50	28.50
149	202.25	6.00	10278.75	38.63	35.00	226.00	3.56	40.48	191.00	5.30	9894.38	27.88
150	201.75	5.99	10396.25	39.75	34.25	225.00	3.58	42.01	190.75	5.31	10060.00	29.25
151	202.38	6.01	10475.00	38.75	32.88	224.50	3.60	45.21	191.63	5.35	10139.38	28.25
153	196.00	5.86	9871.25	38.38	35.38	221.00	3.52	38.92	185.63	5.22	9566.25	27.75
154	180.08	5.71	9217.92	40.08	35.75	204.25	3.40	37.23	168.50	5.05	8836.67	28.33
155	181.75	5.72	9253.75	39.88	36.13	206.50	3.41	37.52	170.38	5.06	8875.00	28.13
156	167.50	5.45	8481.88	40.88	37.38	196.50	3.30	33.38	159.13	4.89	8288.75	29.00
157	174.00	5.59	8866.25	41.00	37.00	201.25	3.35	34.15	164.25	4.98	8592.50	29.00
158	183.63	5.72	9395.00	40.38	36.00	208.63	3.42	37.86	172.63	5.08	9046.88	28.38
159	201.50	6.01	10312.50	38.75	34.25	224.25	3.57	41.86	190.00	5.30	9927.50	28.00
170	152.00	5.26	7231.88	37.63	38.00	182.25	3.18	29.58	144.25	4.72	7176.88	27.25
171	121.31	5.28	6113.13	36.25	34.19	147.19	3.06	24.08	113.00	4.53	5845.94	25.81
172	86.42	4.22	4249.58	38.33	37.42	120.50	2.56	17.29	83.08	3.77	4241.25	27.50
173	98.00	3.94	4451.25	42.75	45.50	139.25	2.41	15.99	93.75	3.57	4426.25	32.25
174	141.63	4.89	6321.25	39.25	43.63	177.13	2.95	24.03	133.50	4.38	6259.38	29.25
175	120.25	4.48	5778.13	42.63	43.13	159.25	2.77	20.66	116.13	4.10	5758.75	31.13
176	103.88	4.22	4822.50	42.75	44.00	142.50	2.58	17.21	98.50	3.82	4806.25	32.13
177	120.38	4.65	5671.88	40.00	41.13	156.25	2.87	21.18	115.13	4.25	5649.38	29.00
178	75.75	3.24	2886.25	45.00	52.75	124.00	1.95	11.98	71.25	2.89	2826.25	33.25
179	101.25	4.03	4432.50	42.25	46.88	143.25	2.47	16.18	96.38	3.66	4379.38	31.00
180	77.50	3.50	3282.50	43.75	48.25	121.25	2.12	12.93	73.00	3.13	3222.50	32.25
181	94.75	3.84	3998.75	43.50	49.00	138.50	2.34	14.86	89.50	3.46	3952.50	32.00
182	124.25	4.61	5782.08	40.75	42.83	161.75	2.84	20.68	118.92	4.21	5747.91	29.75
183	141.38	4.84	6796.88	40.50	42.13	179.00	3.02	23.99	136.88	4.48	6689.38	29.25

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
184	82.50	3.64	3388.75	41.50	47.25	125.00	2.21	13.70	77.75	3.27	3341.25	31.25
221	178.50	5.39	8711.25	41.00	39.00	208.00	3.35	33.28	169.00	4.97	8640.00	30.50
222	178.50	5.45	8592.50	39.75	37.75	205.25	3.36	34.19	167.50	4.99	8565.00	29.25
223	211.25	6.06	10681.25	38.00	34.50	235.50	3.63	44.99	201.00	5.40	10382.50	27.25
224	200.25	5.92	10131.25	38.50	34.75	224.75	3.56	41.47	190.00	5.29	9856.25	28.00
225	203.00	5.97	10363.75	39.00	34.25	227.75	3.61	43.25	193.50	5.36	10126.25	28.25
300	217.33	6.22	11120.01	37.50	32.58	238.92	3.73	45.33	206.33	5.55	10783.76	27.00
301	210.08	6.15	10686.24	36.83	32.50	231.00	3.69	45.02	198.50	5.48	10336.65	26.58
302	217.75	6.20	11065.63	37.38	33.38	238.00	3.68	43.53	204.63	5.47	10611.25	27.00
303	174.31	5.62	8840.31	40.00	35.81	201.94	3.43	33.74	166.13	5.09	8704.06	29.38
304	216.50	6.11	10872.50	37.25	34.00	239.00	3.67	44.88	205.00	5.45	10558.75	27.00
305	220.50	6.29	11286.25	37.13	32.13	239.00	3.73	48.92	206.88	5.55	10818.75	27.00
306	215.33	6.16	10925.02	37.50	33.42	236.92	3.68	44.00	203.50	5.47	10562.94	27.33
307												
308	212.25	6.14	10794.58	38.17	33.75	234.08	3.66	42.69	200.33	5.45	10436.25	28.00
309	201.25	6.06	10276.25	37.50	32.75	224.00	3.64	41.03	191.25	5.41	10013.75	27.50
310	209.50	6.11	10665.01	37.42	32.92	232.33	3.69	43.60	199.42	5.49	10398.34	26.83
311	196.88	5.80	9665.63	38.00	37.25	224.88	3.51	35.17	187.63	5.21	9452.50	27.63
312	221.58	6.31	11395.84	37.25	31.92	240.83	3.76	46.33	208.92	5.59	10952.51	26.92
313	217.58	6.22	11077.07	36.92	32.67	237.75	3.70	45.26	205.08	5.50	10657.91	26.67
314	207.50	6.09	10588.75	37.25	32.75	229.50	3.66	44.29	196.75	5.44	10265.00	27.00
315	159.88	5.39	7993.75	41.13	38.50	191.00	3.28	26.74	152.50	4.87	7874.38	31.00
316	211.25	6.15	10752.50	37.25	32.75	232.50	3.68	46.26	199.75	5.47	10415.00	27.00
434	182.13	5.71	9284.38	39.88	36.13	206.50	3.40	37.46	170.38	5.05	8875.00	28.25
435	179.38	5.66	9194.38	40.75	35.88	206.50	3.43	37.58	170.63	5.09	8994.38	28.50
436	166.25	5.47	8383.75	40.25	37.25	195.75	3.31	33.65	158.50	4.92	8210.00	28.50
437												
438	197.25	5.92	10044.58	38.25	34.00	221.33	3.56	41.60	187.33	5.29	9770.41	27.75
439	171.50	5.35	8420.00	38.75	37.50	201.75	3.35	33.61	164.25	4.97	8331.25	28.25
440	197.75	5.90	10069.59	38.83	34.42	221.92	3.55	42.37	187.50	5.28	9794.59	28.25
441	190.38	5.80	9578.13	37.63	34.50	215.88	3.52	41.19	181.38	5.23	9365.63	26.88
442												
443	189.13	5.81	9444.38	38.25	35.88	215.50	3.50	36.84	179.63	5.21	9206.88	27.75
444												
445	185.75	5.70	9453.75	40.50	36.50	211.25	3.41	38.25	174.75	5.07	9117.50	28.50
458	116.00	4.43	5345.82	41.33	43.92	154.58	2.73	19.30	110.67	4.04	5287.91	30.50
459	103.13	4.08	4548.13	42.38	46.50	144.38	2.50	16.75	97.88	3.70	4501.88	31.38
461	114.50	4.39	5247.50	41.50	44.25	153.50	2.70	18.63	109.25	4.00	5201.25	30.75
462	99.25	3.99	4222.50	43.00	48.25	142.00	2.43	15.11	93.75	3.60	4188.75	32.25
463	112.92	4.37	5182.51	41.92	44.00	151.33	2.68	18.37	107.33	3.97	5168.76	31.42
464	119.75	4.69	5916.25	40.75	39.63	154.63	2.91	21.97	115.00	4.31	5856.88	29.50
465	168.44	5.54	8196.25	37.44	37.13	197.94	3.34	30.23	160.81	4.96	8070.31	26.81
466	127.25	4.66	6052.50	41.00	42.25	164.50	2.89	21.40	122.25	4.28	5993.75	30.00
467	111.13	4.26	5095.63	41.00	44.38	151.25	2.61	18.31	106.88	3.87	5023.13	30.75
468	88.88	3.67	3848.44	42.94	48.25	133.25	2.24	14.46	85.00	3.32	3745.31	32.19
470	91.00	3.81	4073.75	44.50	47.25	133.25	2.33	14.72	86.00	3.44	4038.75	33.00
471	145.25	4.81	6857.50	41.75	44.00	184.25	2.99	22.59	140.25	4.43	6798.75	31.00
472	103.63	4.11	4958.13	43.00	43.88	143.25	2.53	17.48	99.38	3.75	4885.63	32.75

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
473	148.63	5.26	7039.38	36.13	37.00	179.00	3.19	30.03	142.00	4.74	7016.88	26.00
474	150.75	5.22	6967.50	36.38	38.50	181.63	3.16	29.23	143.13	4.69	6954.38	26.50
475	146.75	5.11	6933.75	38.13	39.13	179.63	3.12	28.50	140.50	4.63	6930.00	27.50
476	103.50	4.18	4985.00	43.63	43.31	141.88	2.55	17.39	98.56	3.77	4957.81	33.38
477	102.92	4.59	5114.17	37.08	35.67	135.08	2.80	20.49	99.42	4.13	5105.42	26.50
478	99.00	4.58	4902.50	36.13	35.13	130.50	2.77	20.19	95.38	4.09	4863.75	25.75
479	136.38	5.05	6854.38	40.75	37.75	168.25	3.10	26.34	130.50	4.59	6810.00	29.13
480	127.25	4.56	6006.25	41.75	43.25	165.75	2.81	20.63	122.50	4.17	5982.50	31.25
481	145.25	5.17	6716.25	36.88	38.75	176.38	3.13	27.25	137.63	4.65	6703.13	26.50
482	154.63	5.35	7363.13	36.75	38.00	185.00	3.22	28.04	147.00	4.77	7231.25	26.25
483	140.00	5.01	6542.50	38.00	39.75	173.75	3.07	27.01	134.00	4.55	6533.75	27.00
484	101.50	4.66	5003.75	37.25	36.50	132.50	2.75	19.36	96.00	4.07	4871.25	26.75
485	91.25	4.35	4752.50	40.50	37.00	124.75	2.63	18.41	87.75	3.89	4720.00	28.50
486	169.63	5.43	8346.25	36.88	35.63	199.63	3.36	34.41	164.00	4.98	8318.75	27.50
487	107.75	4.79	5506.25	38.25	35.75	139.00	2.85	21.80	103.25	4.21	5400.00	27.50
488	93.38	3.89	3988.13	42.63	47.00	134.88	2.35	15.13	87.88	3.48	3978.13	32.25
489	153.50	5.63	7200.00	35.88	38.25	179.25	3.23	25.30	141.00	4.79	6824.38	25.31
490	130.88	4.60	6354.38	43.88	43.75	170.00	2.85	21.78	126.25	4.23	6324.38	33.25
498	216.50	6.00	10730.00	39.00	38.25	240.25	3.51	39.43	202.00	5.21	10171.25	28.25
499	167.88	5.20	8093.13	41.38	41.00	201.00	3.23	28.15	160.00	4.79	8035.63	30.88
500	192.00	5.79	9647.50	38.00	34.25	217.75	3.55	40.60	183.50	5.27	9531.25	27.50
501	217.17	6.14	11238.33	40.25	34.50	240.08	3.65	45.95	205.58	5.43	10825.41	28.83
502	219.38	6.16	11301.25	40.13	34.88	241.88	3.65	45.82	207.00	5.43	10848.75	29.00
503	216.25	6.18	11208.33	39.75	33.92	237.00	3.66	45.88	203.08	5.43	10708.33	28.50
504	215.17	6.21	11134.38	39.38	33.62	237.25	3.70	45.51	203.63	5.49	10727.50	28.54
505	192.75	5.78	9619.69	38.88	35.81	219.06	3.51	39.66	183.25	5.22	9453.44	28.06
506	207.50	6.01	10565.00	38.50	34.50	232.00	3.60	43.10	197.50	5.36	10255.00	28.00
507	201.40	5.96	10269.50	39.55	34.70	221.75	3.55	40.88	187.05	5.27	9813.25	28.75
508	218.08	6.22	11244.60	38.75	33.50	236.42	3.65	45.62	202.92	5.43	10644.60	28.08
509	192.63	5.97	9833.13	39.13	35.13	217.25	3.55	38.59	182.13	5.28	9486.25	27.88
510												
511												
512	203.92	5.89	10259.17	39.75	36.00	226.92	3.53	40.33	190.92	5.24	9902.09	28.75
513	190.75	5.83	9608.75	39.50	36.00	213.25	3.48	36.19	177.25	5.17	9195.00	28.75
514	211.00	6.10	10953.75	39.75	33.25	234.38	3.67	45.73	201.13	5.46	10673.75	28.25
515	175.00	5.33	8416.25	40.25	39.38	204.63	3.31	31.05	165.25	4.91	8345.63	29.75
516	192.50	5.76	9656.65	38.50	35.00	219.25	3.54	39.27	184.25	5.26	9544.98	27.92
517	185.50	5.67	9346.25	39.25	35.25	213.75	3.53	37.60	178.50	5.24	9305.00	28.50
518	185.00	5.65	9143.13	38.63	35.63	211.25	3.47	36.76	175.63	5.16	9066.25	28.13
519	169.25	5.32	8343.75	39.75	38.13	200.25	3.33	31.23	162.13	4.94	8260.63	29.38
520	160.94	5.05	7778.75	41.81	42.19	195.81	3.16	27.05	153.63	4.69	7645.63	31.38
521	217.88	6.15	11178.75	39.50	34.63	240.50	3.64	46.07	205.88	5.41	10756.88	28.75
522	213.50	6.14	11055.00	39.25	33.25	236.50	3.67	46.47	203.25	5.46	10732.50	28.50
523	224.13	6.28	11526.88	39.38	34.50	244.50	3.68	44.39	210.00	5.46	10963.13	28.38
524	221.13	6.16	11186.88	38.50	35.25	244.25	3.65	41.86	209.00	5.42	10758.75	27.75
525	189.50	5.66	9415.63	39.63	35.88	216.50	3.50	37.33	180.63	5.20	9387.50	28.88
526	219.75	6.28	11391.25	38.50	32.75	239.50	3.71	48.11	206.75	5.51	10883.75	27.75
527	206.75	6.02	10575.00	38.50	33.50	230.75	3.63	45.32	197.25	5.40	10337.50	27.75

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
528	215.88	6.17	11173.75	39.63	33.75	235.13	3.63	45.33	201.38	5.39	10626.88	28.88
529	171.75	5.21	8120.63	41.00	41.38	202.88	3.23	29.88	161.50	4.80	8039.38	30.50
530	220.25	6.21	11321.25	39.25	34.00	241.25	3.67	45.81	207.25	5.46	10861.25	28.50
531	216.25	6.14	11050.00	39.08	34.67	238.00	3.63	43.36	203.33	5.40	10586.25	28.42
532	220.00	6.25	11403.75	39.25	33.50	241.25	3.69	46.69	207.75	5.48	10933.75	28.50
533	209.25	6.04	10747.50	39.25	34.25	231.25	3.60	43.26	197.00	5.35	10325.00	28.00
534	168.75	5.30	8002.09	39.17	39.92	200.42	3.26	29.15	160.50	4.85	7953.75	28.58
535	190.40	5.63	9311.00	39.60	37.90	217.95	3.43	33.82	180.05	5.10	9164.00	28.70
536	204.25	5.90	10355.00	39.75	35.50	228.75	3.55	41.76	193.25	5.28	10066.25	29.25
537	197.50	5.82	9875.00	38.50	35.75	223.50	3.52	38.37	187.75	5.23	9648.75	28.00
538	200.56	5.92	10140.94	39.25	35.56	225.44	3.54	40.89	189.88	5.27	9844.06	28.06
539	199.75	5.97	10248.75	39.50	34.50	223.25	3.58	42.46	188.75	5.31	9912.50	28.00
540	186.13	5.66	9246.88	39.63	36.00	209.50	3.45	36.15	173.50	5.12	9019.38	29.13
541	228.13	6.37	12000.00	40.50	32.75	247.75	3.77	48.11	215.00	5.60	11486.25	29.00
542	217.13	6.09	11034.38	39.88	36.00	240.50	3.61	44.27	204.50	5.36	10593.13	29.13
543	187.75	5.54	9197.50	41.00	38.50	216.75	3.42	33.78	178.25	5.08	9150.00	30.75
544	190.00	5.64	9452.50	40.50	36.25	215.50	3.46	37.67	179.25	5.14	9366.25	29.75
545	201.42	5.85	10268.75	40.33	35.00	226.67	3.58	42.00	191.67	5.31	10090.00	29.25
546	200.00	5.90	10095.00	39.00	35.25	221.75	3.52	39.97	186.50	5.23	9681.25	28.75
547	219.25	6.17	11223.75	39.50	35.25	242.50	3.65	45.46	207.25	5.43	10766.25	28.25
571	147.50	4.99	7036.25	41.00	41.50	183.00	3.08	24.22	141.50	4.56	7027.50	30.75
20	97.88	3.96	4325.63	39.44	43.50	137.00	2.42	17.30	93.50	3.57	4289.06	31.75
21	92.00	3.91	4009.06	38.81	43.19	131.00	2.38	16.42	87.81	3.52	3975.00	30.25
22												
23	97.69	3.89	4225.63	40.75	45.56	138.56	2.36	16.86	93.00	3.49	4192.81	32.63
24	99.17	3.95	4422.08	40.00	44.25	139.08	2.42	17.11	94.83	3.58	4337.92	32.00
25	85.00	3.79	3833.75	40.04	42.50	123.42	2.30	15.39	80.92	3.40	3812.30	31.04
26	99.56	4.01	4422.19	38.94	43.19	138.44	2.45	17.90	95.25	3.62	4358.75	30.88
27	100.06	3.94	4232.81	38.88	45.44	141.06	2.41	17.09	95.63	3.56	4157.81	30.81
28												
29	103.25	4.01	4490.89	40.04	45.14	143.68	2.44	18.05	98.54	3.61	4441.61	32.18
30	102.95	4.04	4572.75	39.95	43.70	141.90	2.46	18.24	98.20	3.64	4553.75	32.20
31												
32												
33												
34	86.08	3.46	3521.25	44.00	50.50	132.00	2.10	13.70	81.50	3.11	3457.50	35.00
35	85.75	3.44	3512.00	45.30	51.50	132.25	2.08	13.44	80.75	3.08	3448.50	36.00
36	86.50	3.42	3507.75	44.55	51.35	133.05	2.08	13.85	81.70	3.08	3439.00	35.60
37	85.58	3.46	3411.05	43.54	50.67	131.25	2.09	13.60	80.58	3.09	3352.30	34.63
38	87.33	3.48	3447.08	43.96	51.63	133.96	2.10	13.74	82.33	3.11	3388.33	35.17
39	85.50	3.38	3375.63	44.29	51.79	132.38	2.05	13.48	80.58	3.03	3316.67	35.04
40	83.96	3.41	3593.54	45.75	50.38	129.83	2.07	13.44	79.46	3.07	3533.54	36.67
41	87.38	3.52	3685.94	44.56	49.88	132.50	2.14	14.17	82.63	3.17	3626.56	35.75
42	95.85	3.63	3703.50	45.85	54.50	144.40	2.17	14.31	89.90	3.22	3673.25	37.40
43	86.00	3.39	3649.58	46.67	51.42	132.42	2.05	13.75	81.00	3.04	3598.74	37.67
98	73.96	3.17	2869.58	43.21	50.88	120.67	1.92	12.17	69.79	2.84	2761.24	33.96
99	72.79	3.08	2779.17	43.92	51.75	120.29	1.86	12.05	68.54	2.75	2682.92	34.83
100	81.75	3.26	3423.75	45.63	51.13	128.38	1.98	13.40	77.25	2.93	3340.00	36.88

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
101	82.44	3.32	3374.38	44.63	50.75	128.56	2.01	13.41	77.81	2.98	3308.75	36.00
102	78.15	3.24	3091.25	45.80	52.55	126.10	1.96	12.37	73.55	2.90	3036.25	35.75
103	78.88	3.37	3204.06	41.56	47.94	122.56	2.05	13.37	74.63	3.03	3125.63	33.31
104	77.75	3.25	3011.25	42.50	50.50	124.00	1.98	12.83	73.50	2.93	2915.00	34.00
105	75.50	3.24	3052.50	44.25	50.63	121.75	1.96	12.33	71.13	2.91	2950.63	34.75
106	77.50	3.15	2865.00	46.00	54.75	127.38	1.89	12.10	72.63	2.80	2800.00	36.75
185	100.50	3.96	4693.13	41.88	43.63	139.50	2.46	17.94	95.88	3.65	4627.50	34.00
186	97.17	3.91	4367.09	42.75	46.00	138.33	2.42	16.53	92.33	3.58	4307.93	34.25
187												
188												
189	102.00	3.97	4625.00	42.00	44.75	142.00	2.46	17.77	97.25	3.64	4601.25	34.00
190	100.17	4.01	4770.83	43.33	43.17	138.17	2.47	17.37	95.00	3.65	4765.83	35.17
191	104.17	4.14	4732.08	40.75	43.75	142.92	2.57	18.45	99.17	3.81	4673.33	32.83
192												
193												
194	100.00	3.98	4698.34	42.67	43.50	138.58	2.46	17.73	95.08	3.64	4675.01	34.67
195	99.58	3.87	4671.67	43.75	45.67	140.75	2.41	16.76	95.08	3.57	4572.09	35.50
196	106.50	4.23	4955.63	39.38	41.50	143.00	2.63	19.84	101.50	3.90	4873.13	31.63
197	107.88	4.23	5085.63	39.00	40.63	143.88	2.64	20.38	103.25	3.91	5008.13	31.25
237	102.81	4.02	4612.81	41.31	44.75	142.94	2.45	17.92	98.19	3.62	4582.81	33.44
238	89.67	3.87	3971.25	39.50	42.83	128.25	2.34	16.17	85.42	3.46	3954.16	30.58
239												
240												
241	77.75	3.71	3578.75	39.00	40.50	114.25	2.22	14.57	73.75	3.28	3545.00	30.00
242	93.25	3.91	4130.63	40.50	43.88	132.88	2.37	16.32	89.00	3.51	4129.38	31.75
243												
244	94.75	3.81	4135.00	40.75	45.75	136.38	2.32	16.24	90.63	3.44	4056.25	32.38
245	100.83	3.99	4447.91	40.58	44.42	140.50	2.42	17.73	96.08	3.59	4439.99	32.58
246	91.13	3.93	4180.00	37.00	39.50	126.63	2.41	16.94	87.13	3.56	4118.75	28.75
247												
248	84.00	3.43	3545.63	46.00	50.75	129.75	2.07	13.35	79.00	3.06	3498.75	36.50
249	84.00	3.40	3560.00	45.75	50.75	130.25	2.07	13.24	79.50	3.06	3500.00	36.50
250	86.50	3.50	3612.50	43.00	48.75	130.50	2.13	14.06	81.75	3.16	3541.25	34.00
251	83.75	3.39	3533.13	46.06	50.81	129.56	2.05	13.24	78.75	3.04	3486.25	36.81
252	82.25	3.34	3513.44	46.56	51.00	128.63	2.03	13.14	77.63	3.00	3459.69	37.31
253	88.17	3.59	4007.92	43.83	46.75	130.83	2.21	15.00	84.08	3.28	3927.09	35.42
254	90.75	3.62	3906.25	43.88	48.38	134.00	2.20	14.97	85.63	3.26	3853.75	35.75
255	87.13	3.49	3570.63	44.25	50.25	132.25	2.11	14.03	82.00	3.12	3530.00	35.50
256	82.94	3.40	3462.81	45.69	50.63	128.56	2.05	13.24	77.94	3.04	3427.81	36.56
257	90.50	3.57	3895.63	44.38	49.50	135.25	2.19	14.64	85.75	3.24	3800.63	35.63
258	92.38	3.65	4120.00	45.50	49.25	136.88	2.24	15.06	87.63	3.32	4025.00	37.00
259	65.75	3.02	2326.25	43.75	52.00	113.13	1.80	10.92	61.13	2.66	2272.50	32.69
260	87.63	3.71	3787.19	40.69	44.81	127.63	2.25	14.96	82.81	3.33	3748.75	32.44
261	86.75	3.45	3505.00	44.50	51.25	133.00	2.09	13.55	81.75	3.10	3446.25	35.50
262	85.83	3.47	3651.67	45.25	50.42	131.75	2.12	13.65	81.33	3.13	3575.84	36.08
263	85.63	3.49	3676.88	44.63	49.25	130.38	2.13	13.86	81.13	3.15	3616.88	35.63
264	86.50	3.51	3709.17	43.50	48.42	130.50	2.15	14.27	82.08	3.18	3637.09	35.08
265	86.75	3.57	3742.50	43.75	48.00	129.75	2.16	14.16	81.75	3.20	3683.75	34.75

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
266	86.00	3.41	3322.50	45.00	52.75	133.25	2.05	13.41	80.50	3.03	3288.75	36.00
267	87.00	3.48	3731.25	46.00	50.00	132.00	2.12	13.93	82.00	3.13	3720.00	36.75
268	80.25	3.32	3372.50	45.25	50.00	125.75	2.02	13.21	75.75	2.98	3336.25	36.00
269	87.00	3.46	3636.25	45.00	50.50	132.50	2.10	13.79	82.00	3.11	3577.50	35.75
270	83.25	3.52	3525.00	40.75	46.50	125.75	2.17	14.20	79.25	3.20	3416.25	32.75
360	73.00	3.09	2856.88	44.63	51.75	120.50	1.87	12.00	68.75	2.76	2760.63	35.38
361	72.38	3.05	2766.25	44.13	51.75	119.88	1.84	12.07	68.13	2.72	2681.88	35.13
362	75.67	3.23	3041.67	44.00	50.50	121.92	1.96	12.38	71.42	2.90	2953.33	34.75
363	75.38	3.20	3046.88	44.13	50.63	121.75	1.94	12.38	71.13	2.87	2938.75	34.88
364	78.75	3.28	3029.06	43.31	51.00	125.00	1.98	12.79	74.00	2.93	2969.69	34.25
365	81.67	3.27	3307.51	45.67	52.00	128.92	1.98	13.11	76.92	2.93	3244.17	36.50
366	81.38	3.29	3200.00	44.75	51.50	127.75	1.98	13.18	76.25	2.93	3171.25	36.25
367	84.31	3.42	3426.56	43.75	50.19	129.88	2.08	13.62	79.69	3.07	3372.81	35.13
368	79.81	3.28	3352.81	45.31	50.81	126.56	2.01	13.09	75.75	2.97	3265.00	36.25
369	74.88	3.13	2793.44	45.69	53.88	123.94	1.88	11.98	70.06	2.78	2725.31	36.75
370	79.92	3.29	3156.24	44.75	51.67	126.75	1.98	12.64	75.08	2.93	3097.07	35.33
371	81.50	3.32	3337.50	45.50	51.25	127.75	2.00	13.04	76.50	2.96	3278.75	36.50
372	82.83	3.38	3406.26	43.83	49.83	128.08	2.05	13.52	78.25	3.04	3342.51	34.83
373	88.33	3.43	3298.75	47.42	55.83	137.50	2.04	13.11	81.67	3.02	3283.75	38.50
374	84.44	3.38	3431.25	44.88	51.19	130.69	2.05	13.56	79.50	3.03	3375.31	36.06
375	72.75	3.06	2687.50	45.50	53.50	121.50	1.83	11.67	68.00	2.70	2640.00	35.75
376	73.33	3.11	2835.42	44.33	51.58	120.17	1.86	12.05	68.58	2.75	2740.42	35.00
377	81.30	3.34	3353.75	44.45	50.30	127.10	2.03	13.18	76.80	3.00	3284.25	35.75
378	88.13	3.51	3523.75	46.00	52.75	135.38	2.11	13.41	82.63	3.13	3490.00	36.63
379	79.25	3.24	3046.24	45.58	53.29	127.42	1.95	12.49	74.12	2.89	2973.95	36.63
380	89.94	3.75	3624.06	41.88	48.38	132.25	2.20	13.97	83.88	3.25	3576.25	33.25
381	75.13	3.06	2686.25	46.13	55.38	125.50	1.83	11.77	70.13	2.71	2627.50	37.00
382	86.50	3.23	3031.25	50.25	60.75	140.25	1.92	12.05	79.50	2.85	2977.50	41.00
491	90.67	3.77	3495.00	35.92	44.75	130.42	2.27	15.58	85.67	3.36	3444.17	28.17
492	77.00	3.25	2948.75	43.00	50.75	123.25	1.97	12.48	72.50	2.91	2888.75	33.75
494	74.50	3.11	2608.75	44.13	54.00	123.75	1.86	11.88	69.75	2.76	2549.38	35.13
495	73.71	3.10	2701.79	44.36	52.86	121.82	1.86	11.99	68.96	2.75	2640.72	35.18
496	76.75	3.25	3019.38	43.00	50.13	122.38	1.97	12.73	72.25	2.91	2935.63	33.88
497	77.25	3.33	3128.75	41.75	48.00	121.00	2.02	13.09	73.00	2.99	3056.25	32.75
548	102.38	4.15	4643.75	38.38	41.75	139.38	2.59	19.23	97.63	3.83	4560.63	30.75
549												
550	101.25	3.99	4635.00	41.50	44.50	141.00	2.48	17.54	96.50	3.68	4540.00	33.50
551	106.75	4.14	5136.25	41.63	41.88	144.00	2.59	20.02	102.13	3.83	5082.50	33.75
552												
553	97.25	3.89	4243.75	43.00	47.50	139.75	2.40	16.27	92.25	3.56	4185.00	34.00
554												
555	97.50	3.91	4531.88	41.75	43.38	136.38	2.42	17.48	93.00	3.58	4495.63	33.88
556	102.83	4.08	4706.67	39.75	43.25	141.42	2.56	18.38	98.17	3.78	4575.83	32.00
557	110.75	4.29	5062.50	37.75	41.00	147.00	2.68	20.65	106.00	3.96	4991.25	30.00
558												
559	109.00	4.18	5244.58	42.08	42.33	146.67	2.61	20.38	104.33	3.86	5192.91	34.33
560	97.00	3.91	4327.50	42.50	46.75	139.00	2.43	16.33	92.25	3.60	4208.75	33.00
561	100.13	3.99	4447.50	42.63	46.63	141.88	2.48	16.66	95.25	3.66	4382.50	33.50

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
562	103.87	4.04	4841.87	41.33	43.25	142.46	2.51	18.51	99.21	3.72	4778.33	33.46
563	100.75	4.06	4607.92	42.67	45.00	140.58	2.52	17.33	95.58	3.72	4557.50	33.67
564	107.08	4.23	4834.59	43.00	45.67	147.00	2.60	17.37	101.33	3.85	4813.34	33.92
565	108.00	4.20	5170.83	41.25	41.67	145.00	2.61	20.17	103.33	3.87	5127.08	33.50
566	105.13	4.15	4996.25	39.75	41.00	141.63	2.60	19.73	100.63	3.84	4912.50	32.25
567												
568	101.90	3.95	4753.50	42.45	44.50	141.75	2.46	17.61	97.25	3.64	4667.75	34.40
575	82.63	3.52	2809.38	39.75	51.13	128.25	2.08	13.05	77.13	3.08	2775.63	31.75
15	106.91	4.07	5041.17	40.86	42.00	144.19	2.52	19.50	102.19	3.73	5001.02	31.72
16	113.00	4.18	5454.09	40.77	40.84	149.20	2.59	20.80	108.36	3.84	5411.70	31.59
17	132.80	4.89	6746.50	39.00	35.35	162.85	3.05	25.65	127.50	4.51	6721.75	29.65
18	106.06	4.02	4893.13	40.69	42.81	144.06	2.48	19.08	101.25	3.67	4860.63	31.56
19	104.00	4.00	4876.67	40.75	42.25	141.75	2.47	18.79	99.50	3.66	4832.50	31.50
226	108.75	4.09	5201.25	40.50	41.00	145.25	2.53	20.21	104.25	3.74	5165.00	31.25
227	112.58	4.24	5496.26	40.33	40.08	148.25	2.64	20.87	108.17	3.91	5432.09	31.17
228	110.75	4.14	5194.38	39.88	41.63	147.88	2.57	20.11	106.25	3.80	5146.25	30.63
229	64.38	3.01	2121.88	44.63	53.25	112.00	1.75	10.55	58.75	2.59	2118.13	33.00
230	112.25	4.23	5373.13	41.25	41.25	148.38	2.61	20.18	107.13	3.87	5356.25	32.25
231	94.00	3.77	4151.25	43.00	46.25	135.00	2.29	15.81	88.75	3.40	4128.75	33.50
232	108.50	4.06	5133.75	42.00	42.88	146.56	2.50	19.46	103.69	3.70	5101.25	32.81
233	102.75	3.90	4664.59	40.67	44.00	142.42	2.41	18.19	98.42	3.57	4604.17	31.42
234	111.13	4.08	5320.00	41.13	41.75	148.38	2.53	20.60	106.63	3.74	5271.88	31.88
235	105.75	4.04	4858.75	40.75	43.00	143.75	2.49	18.77	100.75	3.68	4823.75	31.25
236	80.75	3.42	3203.75	44.63	50.88	126.38	2.06	12.66	75.50	3.05	3181.25	34.13
572	55.88	2.68	1844.38	44.88	53.00	104.25	1.59	9.87	51.25	2.35	1790.63	34.63
573	79.92	3.34	3484.17	43.00	46.92	122.67	2.04	14.02	75.75	3.02	3415.42	33.67
574	104.63	4.05	4861.88	40.25	42.13	141.75	2.50	18.97	99.63	3.69	4803.13	31.25
1												
2												
3												
4												
5												
6												
7												
8												
9	133.31	5.44	6392.50	28.56	28.81	152.19	3.29	33.86	123.38	4.87	6145.00	19.63
10	128.50	5.50	6288.44	28.25	27.06	145.50	3.32	35.13	118.44	4.92	6034.69	19.31
11	124.50	5.19	5797.50	30.75	32.13	147.38	3.13	28.33	115.25	4.63	5631.88	22.13
12												
13												
14	133.63	5.46	6633.75	31.00	29.00	152.38	3.28	32.82	123.38	4.86	6358.75	21.50
44	128.55	5.60	6275.50	27.00	26.00	147.10	3.44	35.11	121.10	5.09	6150.00	19.25
45	163.39	6.04	8237.51	27.79	24.79	180.36	3.68	46.24	155.57	5.46	8063.58	19.64
46	154.50	6.00	7643.58	24.93	23.07	170.18	3.70	48.06	147.11	5.48	7531.80	17.86
47												
48												
49												
50												

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
51	141.08	5.80	6832.50	25.58	25.33	157.58	3.54	39.71	132.25	5.23	6636.25	17.67
52												
53												
54												
55	144.25	5.87	7046.25	25.42	24.67	159.42	3.55	40.03	134.75	5.26	6808.75	17.83
56	133.42	5.41	6100.83	27.75	31.25	155.67	3.24	28.37	124.42	4.80	5888.33	20.00
57	154.25	5.88	7659.06	26.88	24.69	171.06	3.62	44.74	146.38	5.36	7526.56	19.44
58												
59												
60	142.63	5.81	6905.63	25.63	25.25	158.88	3.54	39.37	133.63	5.24	6716.88	18.13
61	143.00	5.79	6912.50	25.75	25.58	160.08	3.53	38.21	134.50	5.22	6740.83	18.17
72												
73												
74												
75	132.08	5.94	6699.15	26.42	23.67	143.00	3.50	38.58	119.33	5.17	6227.90	18.50
76	125.00	5.50	6060.00	29.75	28.75	140.00	3.24	29.14	111.25	4.79	5657.50	20.75
77	160.38	6.20	8137.50	25.50	23.00	171.00	3.64	49.69	148.00	5.38	7637.50	17.75
78	129.13	5.89	6658.13	26.25	22.63	140.63	3.48	37.69	118.00	5.14	6244.38	19.13
79	125.30	5.67	6241.25	27.55	25.65	140.55	3.38	35.41	114.90	4.99	5925.50	18.95
80	118.63	5.53	5889.69	27.75	26.06	134.31	3.28	32.14	108.25	4.85	5572.81	19.31
81	131.63	5.86	6486.25	24.50	23.50	143.75	3.47	41.82	120.25	5.13	6107.50	16.75
82	146.50	6.20	7372.50	24.00	22.00	154.75	3.64	47.36	132.75	5.39	6827.50	16.00
83	141.50	6.15	7185.83	24.67	22.08	149.17	3.56	45.56	127.08	5.27	6599.58	16.83
84	142.63	6.22	7273.75	24.25	21.63	150.25	3.61	47.12	128.63	5.35	6680.63	16.50
85	124.83	5.66	6111.04	26.63	25.83	139.63	3.36	34.73	113.79	4.97	5764.79	18.29
86	137.92	5.89	6935.42	26.75	24.58	150.67	3.49	39.67	126.08	5.16	6510.00	18.42
87	142.38	6.08	7296.88	26.38	23.00	151.88	3.56	43.65	128.88	5.27	6764.38	18.38
88	138.50	6.11	6909.17	24.00	22.50	146.67	3.55	45.61	124.17	5.24	6350.83	16.17
89	123.75	5.79	6033.13	24.50	24.63	134.50	3.35	33.37	109.88	4.95	5481.88	16.75
90	136.75	6.09	7027.50	26.25	22.25	145.50	3.58	42.14	123.25	5.29	6542.50	18.25
91	122.06	5.31	5764.69	28.63	29.13	141.31	3.22	31.58	112.19	4.77	5561.88	19.06
92												
93												
94	131.25	5.55	6372.50	27.75	27.00	148.75	3.37	38.91	121.75	4.99	6158.75	18.75
95												
96												
97												
117												
118	143.75	5.56	7187.50	31.00	28.50	161.75	3.37	36.00	133.25	5.00	6900.00	22.00
119	141.00	5.45	6800.63	30.25	29.88	160.25	3.28	35.30	130.38	4.86	6554.38	20.75
121												
122	142.63	5.66	7083.75	29.13	27.13	157.50	3.41	38.50	130.38	5.04	6708.75	19.88
123	145.75	5.70	7192.50	28.50	26.50	161.25	3.45	41.92	134.75	5.11	6927.50	19.00
124												
125	111.88	4.99	5273.13	31.88	32.63	138.38	3.06	25.07	105.75	4.52	5216.25	23.25
126												
127	121.38	5.14	5843.13	31.88	31.63	146.38	3.14	26.90	114.75	4.65	5761.25	23.50
128	113.83	5.02	5375.01	31.08	32.00	139.67	3.07	26.45	107.67	4.55	5296.26	22.83

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
129												
130												
131												
132	110.75	4.93	5133.75	31.25	33.00	137.75	3.02	24.64	104.75	4.47	5071.25	23.25
133	114.05	5.05	5507.75	32.55	32.05	139.65	3.09	25.33	107.60	4.56	5427.50	24.00
134	121.94	5.18	5800.00	30.94	31.44	146.50	3.17	27.03	115.06	4.69	5705.63	22.69
135	123.75	5.13	5854.99	31.42	32.50	149.33	3.12	26.09	116.83	4.62	5738.74	23.42
136	109.75	4.90	5155.01	32.42	33.25	136.75	3.00	23.79	103.50	4.43	5095.85	24.00
137	118.63	5.27	5646.25	29.13	29.63	141.63	3.22	28.56	112.00	4.77	5552.50	21.50
138	112.25	5.02	5268.13	31.25	32.38	137.75	3.06	23.80	105.38	4.52	5161.88	22.88
139	138.19	5.47	6737.19	30.50	29.31	160.38	3.37	33.96	131.06	4.99	6665.94	22.56
140	111.33	5.01	5337.08	31.92	31.92	137.17	3.07	25.53	105.25	4.53	5262.50	22.83
141	119.45	5.12	5678.00	31.60	32.15	144.70	3.12	25.97	112.55	4.61	5575.25	23.15
142												
143	118.50	5.23	5758.75	30.25	29.38	142.13	3.23	28.58	112.75	4.78	5720.63	22.50
160	126.50	5.64	6135.00	26.00	25.50	142.00	3.40	39.61	116.50	5.03	5872.50	17.25
161	140.25	5.75	6917.50	28.25	26.75	154.75	3.44	40.92	128.00	5.09	6542.50	19.25
162	145.63	5.72	7210.00	28.88	27.13	161.38	3.44	40.20	134.25	5.09	6878.75	19.38
163	143.58	5.72	7107.91	28.42	26.75	158.83	3.44	40.14	132.08	5.10	6762.49	19.25
164	145.00	5.81	7368.75	29.50	26.00	159.25	3.47	41.28	133.25	5.14	6995.00	20.25
165	125.75	5.60	6133.13	26.75	25.88	141.88	3.38	37.16	116.00	4.99	5883.13	18.00
166	134.00	5.62	6557.50	27.75	26.88	149.88	3.37	38.41	123.00	4.99	6233.13	18.75
167	140.50	5.69	6877.75	28.15	27.30	155.50	3.39	37.89	128.20	5.02	6490.75	19.00
168	142.25	5.76	7112.50	28.00	25.50	157.00	3.47	43.71	131.50	5.14	6812.50	18.63
169	140.00	5.79	6881.25	26.63	25.38	154.50	3.48	43.47	129.13	5.14	6575.00	17.88
198												
200												
201												
202												
203												
205												
206												
207												
208												
209												
210												
211												
212												
213												
214	136.13	5.49	6806.25	31.13	28.63	154.50	3.31	33.81	125.88	4.90	6531.25	21.88
215	134.75	5.49	6624.69	29.81	28.38	153.00	3.32	33.73	124.63	4.91	6367.81	20.81
216	142.25	5.57	6993.75	30.25	29.00	159.50	3.32	33.72	130.50	4.92	6643.75	21.00
217												
218	136.17	5.53	6665.84	28.75	27.58	153.75	3.35	35.39	126.17	4.95	6419.17	19.67
219												
220												
271												
272												

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
273	145.58	5.81	7160.42	26.00	24.33	163.42	3.62	44.63	139.08	5.35	7112.51	18.58
274	150.17	6.02	7500.41	24.83	22.17	165.17	3.73	47.91	143.00	5.52	7403.32	17.75
275	152.06	5.73	7235.00	28.31	29.63	172.44	3.46	35.26	142.81	5.12	7015.94	20.44
276	150.50	5.92	7507.19	26.38	23.94	166.81	3.65	45.25	142.88	5.40	7375.31	18.75
277												
278	135.81	5.66	6731.25	28.06	26.06	154.25	3.48	36.40	128.19	5.15	6599.38	20.06
279	139.38	5.78	6814.38	26.13	25.13	156.25	3.53	38.67	131.13	5.22	6651.25	18.38
280	143.50	5.92	7068.13	25.63	24.50	159.25	3.59	41.06	134.75	5.32	6844.38	17.88
281												
282												
283	144.25	5.87	7070.00	25.75	24.50	159.75	3.58	41.63	135.25	5.30	6881.25	18.00
284												
285												
286												
287	135.63	5.64	6638.75	27.25	26.00	154.38	3.47	35.78	128.38	5.14	6537.50	19.50
288	158.25	5.97	7898.25	26.45	23.85	174.45	3.68	47.04	150.60	5.45	7777.00	18.95
289	142.00	5.51	6625.00	28.75	31.50	164.00	3.29	29.79	132.50	4.87	6363.75	21.00
290	134.00	5.62	6533.75	26.75	25.75	153.00	3.48	37.44	127.25	5.15	6457.50	19.00
291												
292	155.25	5.91	7738.75	27.00	24.25	172.25	3.66	45.95	148.00	5.42	7661.25	19.75
293												
294	143.25	5.86	7043.75	25.88	24.63	158.63	3.56	39.98	134.00	5.26	6818.75	18.13
295	133.50	5.58	6461.25	27.50	27.00	152.75	3.42	34.44	125.75	5.05	6335.00	19.75
296	157.75	6.10	7816.25	25.50	23.50	172.25	3.70	48.57	148.75	5.48	7627.50	18.50
297	135.00	5.61	6548.13	27.38	26.75	154.25	3.45	35.01	127.50	5.10	6434.38	19.75
298	133.00	5.63	6555.00	28.00	26.50	151.50	3.45	34.49	125.00	5.10	6392.50	20.00
299	152.58	5.94	7700.42	26.67	23.25	168.92	3.68	47.53	145.67	5.44	7607.92	19.25
317												
318												
319	160.38	6.25	8297.81	26.00	21.81	170.50	3.68	52.21	148.69	5.46	7832.19	18.38
320	139.88	6.04	7017.50	25.50	24.13	149.63	3.50	39.72	125.50	5.18	6405.63	18.00
321	122.75	5.63	6119.69	27.81	26.00	138.25	3.36	32.48	112.25	4.96	5784.69	19.63
322	138.42	6.13	7039.58	26.33	24.00	146.92	3.53	40.83	122.92	5.22	6367.50	18.17
323	132.25	5.81	6553.13	26.25	24.88	143.63	3.40	36.94	118.75	5.03	6068.13	17.75
324	131.56	5.86	6584.06	25.56	23.63	143.31	3.47	39.89	119.69	5.13	6168.44	17.38
325	132.63	5.95	6785.63	26.25	22.63	143.50	3.53	41.82	120.88	5.22	6388.13	18.13
326	134.83	5.91	6646.67	24.50	23.50	146.50	3.50	40.98	123.00	5.17	6245.00	16.92
327	141.08	6.03	7161.04	25.71	22.58	151.33	3.58	42.53	128.75	5.30	6734.38	18.04
328	138.75	6.02	6937.50	24.75	23.25	150.33	3.56	46.34	127.08	5.26	6496.67	16.33
329	153.44	6.22	7772.81	24.38	21.94	162.81	3.66	50.77	140.88	5.42	7275.31	16.69
330	135.79	5.98	6852.91	26.38	23.63	145.42	3.52	39.34	121.79	5.20	6350.83	18.46
331	128.63	5.80	6330.31	25.25	24.31	142.13	3.45	37.79	117.81	5.10	5979.69	17.00
332	124.38	5.86	6254.38	25.25	23.63	134.25	3.40	35.72	110.63	5.02	5685.63	17.50
333	124.25	5.83	6236.25	25.38	23.38	134.63	3.41	35.88	111.25	5.04	5752.50	18.00
334	128.00	5.68	6043.75	25.25	27.25	141.13	3.28	30.98	113.88	4.85	5503.75	17.25
335	140.00	6.14	6928.75	24.25	23.50	150.25	3.57	46.19	126.75	5.29	6408.75	16.25
336	144.45	6.17	7198.75	24.10	22.75	152.20	3.57	46.09	129.45	5.28	6600.75	16.30
337	131.75	5.87	6540.00	26.50	24.75	144.00	3.46	35.69	119.25	5.12	6128.75	18.25

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
338	152.50	6.15	7807.08	25.58	22.42	163.42	3.62	47.97	141.00	5.36	7350.83	17.92
339	116.63	5.67	5795.63	27.13	26.00	130.13	3.30	31.00	104.13	4.87	5313.13	19.13
340	148.50	5.99	7377.50	27.00	25.50	158.50	3.50	38.66	133.00	5.18	6792.50	18.00
341	130.25	5.79	6560.00	27.50	24.75	143.00	3.43	39.00	118.25	5.07	6173.75	19.00
342	128.75	5.50	6271.25	29.00	27.75	146.75	3.33	36.91	119.00	4.92	6068.75	19.50
343	132.83	5.48	6530.82	29.25	27.83	150.25	3.30	36.12	122.42	4.89	6255.41	20.00
344	130.00	5.51	6238.75	28.25	28.50	147.00	3.29	36.14	118.50	4.87	5901.25	18.75
345												
346												
347	90.75	4.51	3967.50	36.75	40.75	116.00	2.41	15.30	75.25	3.56	3382.50	26.25
348	133.63	5.47	6437.81	28.94	28.50	151.94	3.32	36.77	123.44	4.91	6213.44	19.31
349												
350												
351	129.00	5.44	6283.75	28.75	27.25	147.50	3.32	36.17	120.25	4.91	6155.00	19.75
352	132.75	5.53	6613.75	29.50	27.25	149.75	3.34	36.55	122.50	4.95	6338.75	20.25
353												
354	121.25	5.19	5492.50	28.75	31.50	142.25	3.12	28.54	110.75	4.62	5276.25	19.25
355												
357	144.42	5.68	7110.01	28.83	27.50	160.58	3.41	38.40	133.08	5.05	6780.84	19.17
358												
359	135.75	5.41	6455.00	29.25	30.00	155.50	3.27	33.41	125.50	4.84	6203.75	19.75
383	141.25	5.47	6753.75	29.75	30.25	160.25	3.28	33.83	130.00	4.86	6452.50	20.50
384	140.25	5.51	6727.50	29.50	29.75	157.50	3.30	34.46	127.75	4.88	6363.75	20.00
385												
386												
387	145.25	5.71	7143.75	28.25	26.75	160.25	3.43	41.34	133.50	5.08	6817.50	18.75
388	152.75	5.73	7376.25	28.25	28.00	168.75	3.44	40.39	140.75	5.10	7061.25	18.75
389												
390	145.25	5.54	6977.50	29.00	29.50	162.25	3.32	35.41	132.75	4.92	6590.00	20.00
391	143.33	5.62	6984.58	28.58	27.75	159.75	3.39	37.99	132.00	5.02	6679.17	19.33
392	142.00	5.69	6981.25	28.25	26.50	157.25	3.44	40.61	130.75	5.09	6703.75	18.75
393	146.75	5.69	7218.75	28.50	27.00	162.25	3.43	40.31	135.25	5.08	6905.00	19.50
394	142.75	5.62	7030.63	29.50	27.88	158.38	3.38	37.16	130.50	5.00	6679.38	20.25
395	152.75	5.80	7471.25	28.50	27.75	167.50	3.45	40.75	139.75	5.11	7058.75	19.25
397	161.63	5.94	7986.25	27.75	26.25	174.88	3.55	44.44	148.63	5.25	7573.75	18.50
398	145.25	5.67	7096.25	28.50	27.25	160.50	3.42	39.40	133.25	5.06	6781.25	19.25
399	145.17	5.63	6981.26	28.08	28.17	162.25	3.39	38.46	134.08	5.02	6696.26	18.75
400	140.50	5.30	6502.50	29.88	32.38	161.63	3.18	30.82	129.25	4.70	6225.00	20.50
401												
402												
403	112.50	5.03	5427.09	32.42	31.83	138.08	3.08	26.15	106.25	4.56	5367.92	23.25
404												
405	116.44	5.16	5649.69	31.56	30.88	140.56	3.15	26.03	109.69	4.66	5549.69	23.25
406	118.63	5.14	5741.25	31.75	31.25	143.38	3.15	26.98	112.13	4.66	5653.75	23.50
407	119.83	5.11	5690.82	31.50	32.17	145.17	3.12	25.36	113.00	4.61	5586.65	23.17
408	130.92	5.37	6268.76	30.17	30.25	154.17	3.29	31.09	123.92	4.87	6187.93	22.00
409	119.13	5.12	5635.63	30.88	31.38	144.00	3.15	27.77	112.63	4.66	5583.75	22.75
410	143.63	5.54	6908.13	29.00	29.00	165.38	3.40	34.68	136.38	5.04	6818.75	21.25

AOI ID	Sum DVI	Sum SAVI	Sum TVI	Sum (5) Band 1	Sum (5) Band 2	Sum (5) Band3	Sum (5) NDVI	Sum (5) RVI	Sum (5) DVI	Sum (5) SAVI	Sum (5) TVI	Sum (4) Band 1
411												
412												
413												
414	122.88	5.25	5953.75	31.00	30.50	146.25	3.19	28.45	115.75	4.71	5835.00	22.75
415	114.25	5.06	5581.88	32.75	31.50	139.63	3.11	26.59	108.13	4.59	5525.00	23.75
416												
417												
418												
419	117.63	5.15	5667.50	31.75	31.38	142.00	3.13	26.18	110.63	4.63	5566.88	23.25
420	123.33	5.28	6032.08	30.67	29.50	146.25	3.24	29.98	116.75	4.80	5948.33	22.92
421	110.00	5.05	5298.13	31.13	30.75	134.75	3.10	25.97	104.00	4.59	5235.63	23.13
423												
424												
425												
426	133.42	5.41	6464.99	30.83	30.25	156.33	3.31	31.47	126.08	4.90	6359.57	22.75
427	123.83	5.11	5787.92	31.42	33.17	149.92	3.11	25.34	116.75	4.61	5671.26	23.50
428	109.13	4.95	5135.63	31.25	32.13	135.63	3.04	25.48	103.50	4.49	5091.88	23.25
429												
430	116.50	5.08	5635.00	32.00	31.50	142.00	3.12	26.75	110.50	4.62	5572.50	23.75
431	109.06	4.88	5209.69	33.19	33.19	136.13	2.99	23.82	102.94	4.42	5146.88	24.31
432	123.17	5.21	5984.17	31.92	31.33	147.50	3.18	27.66	116.17	4.70	5863.75	23.42
433	117.38	4.92	5275.00	31.63	35.13	145.75	2.99	22.91	110.63	4.43	5198.75	23.63
446	142.25	5.71	7088.75	28.50	26.25	158.75	3.46	41.82	132.50	5.12	6838.75	19.00
447	129.50	5.60	6403.75	28.00	26.25	146.25	3.39	37.28	120.00	5.01	6166.25	18.75
448	146.33	5.80	7245.42	27.67	25.92	160.33	3.48	42.75	134.42	5.16	6887.08	18.42
449	136.25	5.65	6717.50	28.25	27.00	152.75	3.40	37.31	125.75	5.04	6406.25	19.25
450	136.00	5.62	6621.88	28.50	28.00	152.13	3.35	35.54	124.13	4.95	6253.75	19.25
451	136.63	5.67	6641.25	27.25	27.38	151.25	3.37	36.72	123.88	4.98	6181.88	18.25
452	148.75	5.90	7461.25	27.25	24.63	161.38	3.55	47.74	136.75	5.26	7086.88	18.38
453	139.00	5.78	6926.25	27.25	25.00	153.63	3.49	44.09	128.63	5.16	6645.00	18.38
454	139.67	5.74	6848.75	27.42	26.50	155.00	3.43	39.95	128.50	5.08	6512.08	18.25
455	134.50	5.72	6725.00	28.50	25.75	150.00	3.45	39.88	124.25	5.10	6473.75	19.50
456	132.75	5.77	6471.25	25.75	25.00	147.00	3.46	43.29	122.00	5.12	6171.25	17.00
457	125.00	5.64	6012.50	25.50	25.75	140.00	3.37	37.09	114.25	4.99	5688.75	16.75
594												
595												

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
62	19.30	208.90	3.31	44.48	189.60	4.92	10168.75
63	29.88	146.83	2.58	21.16	116.96	3.83	5978.54
64	19.86	191.46	3.23	39.39	171.61	4.80	9269.10
65	20.94	195.38	3.21	38.39	174.44	4.77	9315.63
66	28.60	136.55	2.55	20.57	107.95	3.78	5535.25
67	20.25	191.90	3.22	38.98	171.65	4.78	9252.25
68	21.19	206.13	3.24	39.73	184.94	4.82	9799.06
69	20.31	197.00	3.23	40.13	176.69	4.80	9469.69
70	20.50	195.56	3.22	39.38	175.06	4.79	9370.63
71	20.92	186.92	3.16	37.44	166.00	4.70	8893.75
107	21.50	189.50	3.17	37.92	168.00	4.70	9041.25
108							
109	22.00	205.38	3.22	38.47	183.38	4.78	9691.25
110	20.25	210.88	3.29	43.53	190.63	4.89	10386.25
111	20.00	210.00	3.30	43.57	190.00	4.90	10271.88
112	20.88	204.38	3.26	40.75	183.50	4.84	9899.38
113	21.25	187.75	3.18	36.91	166.50	4.72	9013.75
114	22.75	189.75	3.12	36.67	167.00	4.64	8825.00
115							
144	20.75	192.25	3.21	39.62	171.50	4.77	9358.75
145	19.88	192.63	3.25	39.94	172.75	4.82	9421.25
146							
147	21.17	191.75	3.20	37.95	170.58	4.75	9257.51
148	23.25	185.25	3.10	32.31	162.00	4.61	8598.75
149	21.25	197.75	3.22	38.42	176.50	4.78	9454.38
150	20.50	197.50	3.24	40.01	177.00	4.82	9681.25
151	19.00	198.00	3.29	43.30	179.00	4.89	9828.75
153	21.50	193.88	3.19	36.96	172.38	4.74	9212.50
154	21.25	179.50	3.14	35.52	158.25	4.66	8585.42
155	21.38	181.25	3.14	35.81	159.88	4.67	8635.00
156	22.63	171.75	3.04	31.70	149.13	4.52	8061.88
157	22.25	176.00	3.09	32.43	153.75	4.59	8328.75
158	21.25	183.25	3.16	36.14	162.00	4.69	8776.88
159	20.50	197.25	3.24	39.89	176.75	4.82	9550.00
170	25.13	155.00	2.83	27.47	129.88	4.19	6695.63
171	22.69	120.94	2.67	21.80	98.25	3.95	5209.38
172	25.33	96.00	2.22	15.26	70.67	3.27	3739.16
173	34.00	105.75	1.92	13.07	71.75	2.84	3421.25
174	30.63	149.63	2.60	21.91	119.00	3.85	5819.38
175	30.88	127.75	2.33	18.09	96.88	3.45	4867.50
176	31.88	112.50	2.16	14.74	80.63	3.19	4055.00
177	28.63	125.50	2.45	18.72	96.88	3.62	4879.38
178	40.25	93.00	1.53	9.50	52.75	2.26	1972.50
179	34.63	111.75	2.03	13.61	77.13	3.01	3511.88
180	35.75	92.00	1.72	10.59	56.25	2.54	2480.00
181	36.38	107.75	1.92	12.42	71.38	2.84	3153.13
182	30.92	129.42	2.38	17.96	98.50	3.53	4814.17
183	29.88	143.63	2.53	21.10	113.75	3.76	5628.13

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
184	35.00	95.50	1.80	11.29	60.50	2.65	2668.75
221	25.25	180.25	3.01	31.27	155.00	4.47	8248.75
222	24.25	179.00	3.04	32.25	154.75	4.52	8212.50
223	19.50	205.50	3.30	42.99	186.00	4.90	10036.25
224	21.00	197.00	3.22	39.45	176.00	4.79	9465.00
225	20.50	197.75	3.24	41.07	177.25	4.81	9598.75
300	19.92	204.67	3.27	42.63	184.75	4.86	9910.42
301	19.42	199.25	3.27	42.60	179.83	4.86	9672.49
302	20.50	207.00	3.27	41.12	186.50	4.86	9942.50
303	23.25	167.19	2.96	30.97	143.94	4.39	7778.75
304	20.25	207.25	3.27	42.57	187.00	4.86	9991.25
305	18.38	207.25	3.34	46.61	188.88	4.96	10263.13
306	20.42	205.00	3.26	41.54	184.58	4.84	9886.26
307							
308	21.25	200.08	3.20	39.97	178.83	4.76	9582.91
309	21.00	193.50	3.20	38.43	172.50	4.75	9242.50
310	19.92	199.00	3.25	41.03	179.08	4.84	9611.26
311	24.75	192.00	3.06	32.54	167.25	4.54	8635.63
312	19.25	207.42	3.31	43.69	188.17	4.92	10136.67
313	19.58	206.75	3.30	42.89	187.17	4.90	10031.24
314	20.00	198.75	3.24	41.87	178.75	4.82	9602.50
315	27.88	158.63	2.78	23.70	130.75	4.12	6834.38
316	19.25	201.25	3.29	43.95	182.00	4.89	9836.25
434	21.50	181.50	3.14	35.75	160.00	4.66	8641.25
435	21.25	179.25	3.13	35.72	158.00	4.65	8588.75
436	22.25	169.25	3.04	31.89	147.00	4.51	7943.75
437							
438	20.25	194.50	3.24	39.65	174.25	4.81	9425.00
439	24.00	174.25	3.00	31.58	150.25	4.46	7916.25
440	20.67	194.42	3.22	40.37	173.75	4.78	9407.92
441	20.50	188.63	3.20	39.25	168.13	4.75	9011.88
442							
443	22.25	186.13	3.14	34.68	163.88	4.66	8716.25
444							
445	21.75	185.50	3.14	36.50	163.75	4.67	8828.75
458	31.50	124.00	2.31	16.83	92.50	3.42	4530.00
459	33.75	113.63	2.08	14.34	79.88	3.09	3768.13
461	32.25	121.00	2.24	15.93	88.75	3.31	4295.00
462	36.00	110.75	1.99	12.56	74.75	2.95	3381.25
463	32.25	119.92	2.22	15.70	87.67	3.29	4304.17
464	27.38	124.63	2.49	19.52	97.25	3.68	5064.38
465	25.81	166.69	2.87	27.47	140.88	4.26	7138.75
466	30.38	131.88	2.42	18.66	101.50	3.59	5039.38
467	33.38	119.38	2.12	15.42	86.00	3.14	4050.63
468	36.25	101.38	1.79	11.80	65.13	2.65	2870.31
470	35.00	101.75	1.89	12.15	66.75	2.79	3147.50
471	31.50	154.00	2.57	20.17	122.50	3.82	6077.50
472	32.63	110.50	2.05	14.56	77.88	3.03	3905.63

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
473	24.25	151.50	2.83	27.87	127.25	4.19	6528.75
474	25.75	154.63	2.80	27.11	128.88	4.16	6515.00
475	26.00	151.63	2.76	26.37	125.63	4.10	6423.75
476	32.19	110.38	2.07	14.56	78.19	3.06	4022.19
477	24.25	109.42	2.41	18.24	85.17	3.56	4472.09
478	23.63	105.50	2.40	18.02	81.88	3.54	4295.63
479	25.50	137.50	2.67	23.83	112.00	3.95	5944.38
480	32.00	132.25	2.31	17.65	100.25	3.43	4941.25
481	25.88	148.38	2.76	25.07	122.50	4.10	6184.38
482	25.38	156.75	2.83	25.80	131.38	4.20	6651.88
483	26.25	144.25	2.70	24.83	118.00	4.00	5971.25
484	24.75	105.25	2.36	17.04	80.50	3.48	4215.00
485	24.25	98.25	2.28	16.33	74.00	3.37	4103.75
486	24.75	170.38	2.90	31.72	145.63	4.30	7542.50
487	23.50	114.00	2.50	19.76	90.50	3.70	4905.00
488	35.38	106.63	1.94	12.70	71.25	2.87	3265.63
489	26.25	146.00	2.76	22.52	119.75	4.10	5898.44
490	32.00	137.25	2.38	18.99	105.25	3.53	5381.25
498	23.25	212.75	3.21	37.60	189.50	4.78	9950.00
499	28.13	172.00	2.84	25.89	143.88	4.22	7455.00
500	20.75	190.25	3.21	38.57	169.50	4.76	9116.25
501	20.17	209.00	3.29	43.78	188.83	4.88	10265.00
502	20.50	210.25	3.28	43.62	189.75	4.88	10295.00
503	19.25	207.08	3.31	43.84	187.83	4.93	10270.41
504	20.04	203.75	3.27	43.05	183.71	4.86	9992.92
505	21.38	190.56	3.18	37.68	169.19	4.73	9094.69
506	20.50	203.25	3.26	41.04	182.75	4.85	9850.00
507	21.05	194.85	3.22	38.91	173.80	4.79	9421.50
508	19.67	208.00	3.31	43.57	188.33	4.92	10216.26
509	20.63	186.00	3.19	36.43	165.38	4.74	8957.50
510							
511							
512	22.00	199.42	3.20	38.36	177.42	4.76	9512.09
513	22.25	185.50	3.14	34.17	163.25	4.67	8780.00
514	19.50	204.38	3.30	43.55	184.88	4.90	10075.00
515	25.75	177.88	2.98	29.09	152.13	4.43	7986.25
516	21.58	189.67	3.17	37.07	168.08	4.70	9005.82
517	21.75	180.25	3.10	35.12	158.50	4.60	8566.25
518	22.13	183.25	3.12	34.68	161.13	4.64	8626.25
519	24.88	172.50	2.97	29.14	147.63	4.41	7808.75
520	29.56	165.81	2.75	24.67	136.25	4.09	6984.69
521	20.25	210.88	3.29	44.01	190.63	4.90	10338.75
522	19.38	206.75	3.31	44.33	187.38	4.92	10235.63
523	20.50	213.13	3.29	42.15	192.63	4.90	10379.38
524	22.00	213.13	3.24	39.51	191.13	4.82	10102.50
525	22.25	187.13	3.14	35.17	164.88	4.66	8873.13
526	18.75	209.00	3.34	45.93	190.25	4.96	10367.50
527	19.50	202.50	3.29	43.30	183.00	4.90	9933.75

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
528	19.75	207.63	3.30	43.36	187.88	4.91	10260.63
529	27.88	175.50	2.89	27.85	147.63	4.30	7630.63
530	20.00	210.50	3.30	43.61	190.50	4.91	10332.50
531	20.75	208.08	3.27	41.22	187.33	4.86	10094.99
532	20.00	210.75	3.30	44.43	190.75	4.91	10345.00
533	20.50	203.50	3.26	41.24	183.00	4.85	9862.50
534	26.67	172.50	2.91	27.04	145.83	4.32	7473.75
535	24.20	189.70	3.09	31.76	165.50	4.59	8702.50
536	21.75	201.00	3.21	39.75	179.25	4.78	9675.00
537	22.00	195.75	3.19	36.35	173.75	4.73	9257.50
538	21.00	197.19	3.22	38.95	176.19	4.79	9480.31
539	19.75	195.00	3.26	40.54	175.25	4.85	9546.25
540	22.25	183.00	3.13	34.23	160.75	4.65	8690.63
541	19.13	213.50	3.34	45.60	194.38	4.96	10656.88
542	21.00	209.88	3.26	42.23	188.88	4.85	10215.63
543	25.25	187.25	3.04	31.55	162.00	4.51	8622.50
544	22.50	189.25	3.15	35.76	166.75	4.68	9026.25
545	21.25	197.17	3.21	39.86	175.92	4.77	9555.84
546	21.75	195.25	3.20	38.01	173.50	4.75	9340.00
547	20.50	210.00	3.28	43.25	189.50	4.88	10211.25
571	30.75	146.75	2.53	20.84	116.00	3.76	5800.00
20	35.81	94.88	1.72	11.82	59.06	2.55	2567.19
21	34.75	93.25	1.74	11.94	58.50	2.58	2497.50
22							
23	37.56	96.56	1.68	11.61	59.00	2.48	2480.94
24	36.25	96.33	1.74	11.77	60.08	2.57	2600.42
25	33.54	87.17	1.70	11.35	53.63	2.51	2443.75
26	35.94	96.63	1.74	12.13	60.69	2.58	2553.44
27	37.63	99.00	1.72	11.71	61.38	2.54	2421.56
28							
29	37.71	99.86	1.73	12.15	62.14	2.55	2581.25
30	36.40	97.95	1.74	12.22	61.55	2.58	2678.50
31							
32							
33							
34	41.53	91.19	1.46	9.15	49.67	2.16	1863.19
35	42.55	91.85	1.44	8.92	49.30	2.13	1842.75
36	42.90	91.85	1.42	8.98	48.95	2.10	1754.00
37	41.88	90.63	1.45	8.98	48.75	2.14	1748.75
38	42.92	93.50	1.46	9.09	50.58	2.15	1792.91
39	42.92	90.58	1.40	8.77	47.67	2.07	1635.21
40	41.29	89.38	1.44	8.98	48.08	2.13	1964.80
41	41.19	92.44	1.50	9.56	51.25	2.22	2045.94
42	45.75	103.35	1.52	9.62	57.60	2.26	2086.75
43	43.08	90.33	1.38	8.70	47.25	2.04	1847.91
98	41.50	83.46	1.32	8.21	41.96	1.96	1381.45
99	42.42	81.83	1.25	7.93	39.42	1.84	1250.42
100	42.50	86.44	1.32	8.53	43.94	1.96	1662.50

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
101	42.06	87.13	1.36	8.64	45.06	2.00	1677.19
102	41.75	89.75	1.42	9.00	48.00	2.10	1830.00
103	39.44	83.31	1.40	8.75	43.88	2.07	1611.88
104	41.75	85.00	1.35	8.37	43.25	1.99	1426.25
105	41.13	85.00	1.38	8.46	43.88	2.03	1588.13
106	45.00	89.13	1.30	8.18	44.13	1.92	1422.50
185	36.63	97.38	1.75	11.92	60.75	2.59	2788.13
186	37.00	103.67	1.83	12.67	66.67	2.71	3072.09
187							
188							
189	37.00	100.50	1.77	12.41	63.50	2.62	2890.00
190	35.75	96.08	1.77	11.70	60.33	2.61	2961.25
191	35.25	108.92	1.97	14.45	73.67	2.92	3453.74
192							
193							
194	36.58	96.58	1.74	11.66	60.00	2.58	2817.92
195	38.08	98.75	1.71	11.22	60.67	2.54	2787.92
196	33.50	104.75	1.98	15.06	71.25	2.93	3384.38
197	33.63	102.38	1.93	14.45	68.75	2.86	3211.88
237	37.25	99.69	1.74	12.15	62.44	2.58	2759.69
238	34.17	91.08	1.72	11.89	56.92	2.54	2505.41
239							
240							
241	32.00	77.75	1.60	10.27	45.75	2.36	2097.50
242	35.50	93.25	1.72	11.59	57.75	2.54	2531.25
243							
244	37.63	94.75	1.65	11.12	57.13	2.44	2357.50
245	37.17	96.92	1.71	11.72	59.75	2.52	2552.08
246	31.75	84.88	1.72	11.55	53.13	2.54	2371.25
247							
248	41.38	90.00	1.45	9.11	48.63	2.15	1968.13
249	41.50	89.50	1.44	8.83	48.00	2.13	1925.00
250	39.75	89.25	1.49	9.48	49.50	2.20	1928.75
251	41.44	88.94	1.43	8.91	47.50	2.11	1935.63
252	41.75	87.75	1.40	8.73	46.00	2.06	1878.44
253	38.75	90.67	1.55	9.98	51.92	2.29	2279.16
254	40.13	92.13	1.53	9.89	52.00	2.27	2184.38
255	41.88	90.75	1.44	9.08	48.88	2.13	1838.13
256	41.63	89.00	1.42	8.85	47.38	2.11	1887.81
257	40.75	94.25	1.54	9.95	53.50	2.28	2188.13
258	41.25	95.75	1.57	9.92	54.50	2.32	2321.25
259	39.50	81.00	1.36	8.35	41.50	2.01	1427.81
260	36.56	87.00	1.59	10.04	50.44	2.35	2130.00
261	42.00	92.25	1.46	9.14	50.25	2.16	1895.00
262	41.33	91.75	1.49	9.25	50.42	2.20	2022.08
263	40.50	90.38	1.49	9.29	49.88	2.20	2030.63
264	40.17	89.50	1.49	9.30	49.33	2.20	1983.76
265	39.25	88.75	1.52	9.48	49.50	2.24	2047.50

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
266	44.00	93.25	1.41	8.84	49.25	2.08	1702.50
267	40.50	90.75	1.49	9.59	50.25	2.20	2156.25
268	40.75	85.50	1.39	8.86	44.75	2.05	1786.25
269	42.00	90.25	1.43	8.82	48.25	2.12	1818.75
270	38.00	87.25	1.53	9.67	49.25	2.26	1963.75
360	42.25	82.13	1.26	7.97	39.88	1.87	1340.63
361	42.63	81.38	1.22	7.86	38.75	1.81	1225.00
362	41.00	84.25	1.36	8.41	43.25	2.01	1568.75
363	41.25	83.38	1.33	8.29	42.13	1.97	1500.63
364	42.13	86.00	1.35	8.40	43.88	1.99	1445.63
365	42.83	88.25	1.34	8.67	45.42	1.99	1669.17
366	43.00	86.75	1.32	8.36	43.75	1.95	1546.25
367	41.50	89.13	1.43	8.93	47.63	2.11	1775.63
368	41.69	88.13	1.39	8.88	46.44	2.06	1805.31
369	44.69	87.56	1.28	8.02	42.88	1.90	1389.69
370	42.00	88.42	1.38	8.68	46.42	2.04	1687.50
371	42.25	88.00	1.37	8.63	45.75	2.02	1741.25
372	41.33	87.17	1.40	8.70	45.83	2.06	1674.17
373	47.17	99.42	1.41	8.72	52.25	2.09	1789.17
374	42.63	89.63	1.39	8.77	47.00	2.06	1726.56
375	43.50	83.75	1.25	7.89	40.25	1.84	1276.25
376	42.25	82.00	1.25	7.96	39.75	1.85	1298.75
377	41.30	87.10	1.40	8.73	45.80	2.06	1762.75
378	43.50	96.38	1.50	9.19	52.88	2.21	1990.63
379	44.00	89.04	1.34	8.36	45.04	1.98	1551.46
380	39.06	90.56	1.56	9.49	51.50	2.31	2022.81
381	45.63	87.25	1.23	7.85	41.63	1.83	1261.88
382	51.00	102.00	1.33	8.13	51.00	1.97	1600.00
491	36.75	89.42	1.60	10.45	52.67	2.36	1817.92
492	41.25	84.75	1.36	8.43	43.50	2.01	1462.50
494	44.50	86.75	1.27	7.99	42.25	1.88	1221.88
495	43.29	84.07	1.26	8.05	40.79	1.86	1269.12
496	41.38	84.00	1.34	8.34	42.63	1.97	1418.75
497	39.50	82.50	1.39	8.57	43.00	2.05	1508.75
548	33.50	103.00	1.96	14.82	69.50	2.90	3213.75
549							
550	36.25	102.63	1.84	12.89	66.38	2.72	3057.50
551	35.25	101.25	1.86	13.57	66.00	2.74	3157.50
552							
553	36.50	108.25	1.92	13.41	71.75	2.84	3350.00
554							
555	36.38	94.25	1.70	11.46	57.88	2.52	2656.25
556	34.83	105.50	1.94	14.11	70.67	2.86	3264.16
557	33.50	106.50	1.99	15.25	73.00	2.94	3317.50
558							
559	35.58	103.25	1.88	13.95	67.67	2.78	3264.58
560	36.00	107.75	1.94	13.43	71.75	2.88	3302.50
561	36.25	109.38	1.96	13.53	73.13	2.90	3395.00

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
562	36.33	100.25	1.79	12.40	63.92	2.65	2922.71
563	35.08	107.25	1.97	13.97	72.17	2.92	3473.76
564	35.58	114.08	2.07	14.10	78.50	3.06	3766.67
565	34.92	102.17	1.88	13.82	67.25	2.79	3227.91
566	33.75	100.13	1.89	14.01	66.38	2.80	3176.25
567							
568	37.55	99.60	1.74	11.55	62.05	2.58	2803.25
575	41.88	94.13	1.51	9.37	52.25	2.23	1650.63
15	34.03	98.22	1.82	13.73	64.19	2.68	2989.69
16	33.27	100.77	1.86	14.40	67.50	2.75	3215.23
17	27.15	112.55	2.33	19.51	85.40	3.44	4507.50
18	34.63	97.56	1.78	13.40	62.94	2.63	2855.94
19	34.08	96.17	1.77	13.21	62.08	2.62	2858.76
226	33.25	98.00	1.81	14.11	64.75	2.67	3047.50
227	32.58	101.00	1.91	14.57	68.42	2.83	3286.26
228	33.38	101.25	1.87	14.46	67.88	2.76	3132.50
229	39.63	80.88	1.36	8.26	41.25	2.01	1433.13
230	33.00	101.63	1.91	14.52	68.63	2.82	3360.00
231	37.50	94.25	1.65	11.16	56.75	2.44	2457.50
232	34.81	100.13	1.80	13.70	65.31	2.66	3075.63
233	35.67	96.00	1.71	12.62	60.33	2.53	2612.92
234	34.25	99.75	1.80	14.12	65.50	2.65	3049.38
235	34.75	98.00	1.79	13.22	63.25	2.65	2830.00
236	39.25	90.75	1.56	9.60	51.50	2.30	2088.13
572	41.63	76.25	1.17	7.41	34.63	1.72	1066.25
573	37.83	84.17	1.43	9.78	46.33	2.11	1920.84
574	34.00	97.63	1.81	13.54	63.63	2.67	2920.00
1							
2							
3							
4							
5							
6							
7							
8							
9	17.56	133.31	3.04	32.18	115.75	4.49	5983.44
10	16.13	127.00	3.07	33.44	110.88	4.54	5846.56
11	20.50	128.00	2.88	26.67	107.50	4.26	5529.38
12							
13							
14	17.88	133.13	3.02	31.09	115.25	4.46	6106.88
44	16.10	125.50	3.07	32.92	109.40	4.54	5769.25
45	15.00	157.61	3.28	43.92	142.61	4.87	7571.43
46	14.54	147.54	3.25	45.41	133.00	4.82	6965.55
47							
48							
49							
50							

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
51	15.33	135.75	3.16	37.53	120.42	4.68	6242.50
52							
53							
54							
55	15.33	139.33	3.19	37.88	124.00	4.72	6437.50
56	20.67	135.25	2.92	26.44	114.58	4.33	5665.83
57	15.69	149.50	3.21	42.35	133.81	4.75	7046.88
58							
59							
60	15.50	137.88	3.17	37.21	122.38	4.70	6368.13
61	15.92	139.25	3.16	36.05	123.33	4.68	6380.42
72							
73							
74							
75	14.25	123.75	3.16	36.54	109.50	4.67	5878.74
76	18.00	120.25	2.95	27.31	102.25	4.36	5373.75
77	13.50	152.50	3.31	47.75	139.00	4.91	7353.75
78	14.63	124.25	3.13	35.64	109.63	4.63	5908.75
79	14.90	121.80	3.10	33.67	106.90	4.59	5729.75
80	15.81	116.81	3.02	30.44	101.00	4.46	5382.50
81	13.38	126.50	3.21	40.11	113.13	4.75	5976.88
82	12.50	136.00	3.31	45.38	123.50	4.90	6507.50
83	12.67	132.42	3.28	43.78	119.75	4.85	6383.34
84	12.13	132.75	3.32	45.28	120.63	4.91	6446.88
85	15.29	120.71	3.08	32.93	105.42	4.55	5555.84
86	14.58	131.67	3.18	37.77	117.08	4.70	6218.34
87	13.75	133.50	3.23	41.66	119.75	4.78	6426.88
88	12.58	129.08	3.27	43.84	116.50	4.83	6165.42
89	15.00	117.75	3.08	31.63	102.75	4.55	5303.75
90	13.00	126.50	3.24	40.09	113.50	4.79	6173.75
91	17.06	122.00	2.99	29.98	104.94	4.43	5436.88
92							
93							
94	14.75	129.50	3.15	37.34	114.75	4.66	6117.50
95							
96							
97							
117							
118	17.75	142.00	3.08	34.17	124.25	4.56	6616.25
119	18.38	140.88	3.03	33.61	122.50	4.49	6350.63
121							
122	15.88	138.38	3.15	36.80	122.50	4.66	6505.00
123	15.25	142.00	3.19	40.21	126.75	4.72	6693.75
124							
125	21.00	116.88	2.76	23.23	95.88	4.08	5007.50
126							
127	21.13	125.88	2.82	24.94	104.75	4.17	5463.13
128	20.92	118.92	2.77	24.58	98.00	4.10	5082.09

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
129							
130							
131							
132	22.25	115.50	2.68	22.58	93.25	3.96	4757.50
133	21.55	117.85	2.74	23.25	96.30	4.05	5047.75
134	20.88	125.25	2.83	25.02	104.38	4.19	5390.94
135	21.75	129.17	2.82	24.22	107.42	4.17	5529.16
136	22.67	115.33	2.66	21.77	92.67	3.93	4760.01
137	19.38	119.88	2.87	26.44	100.50	4.24	5226.88
138	22.13	116.00	2.70	21.68	93.88	3.99	4765.00
139	19.06	137.88	3.00	31.76	118.81	4.44	6273.13
140	20.83	116.17	2.76	23.63	95.33	4.08	4956.66
141	21.45	123.95	2.80	24.03	102.50	4.14	5286.50
142							
143	20.38	119.63	2.80	26.08	99.25	4.15	5164.38
160	14.50	123.00	3.13	37.88	108.50	4.63	5686.25
161	14.75	134.75	3.19	39.25	120.00	4.72	6427.50
162	15.88	141.88	3.17	38.47	126.00	4.69	6632.50
163	15.58	139.25	3.17	38.39	123.67	4.69	6531.66
164	15.25	140.00	3.19	39.49	124.75	4.72	6712.50
165	14.88	122.88	3.11	35.43	108.00	4.60	5696.88
166	15.88	130.88	3.11	36.69	115.00	4.60	6023.13
167	16.10	136.25	3.13	36.17	120.15	4.63	6283.00
168	14.50	137.75	3.20	41.96	123.25	4.74	6554.38
169	14.25	135.25	3.21	41.74	121.00	4.75	6394.38
198							
200							
201							
202							
203							
205							
206							
207							
208							
209							
210							
211							
212							
213							
214	17.63	135.50	3.04	32.09	117.88	4.51	6297.50
215	17.25	133.88	3.06	32.01	116.63	4.52	6169.69
216	18.00	140.25	3.05	31.97	122.25	4.52	6397.50
217							
218	16.83	135.17	3.08	33.66	118.33	4.56	6185.84
219							
220							
271							
272							

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
273	15.33	140.83	3.19	42.12	125.50	4.72	6583.76
274	14.00	142.42	3.25	45.13	128.42	4.82	6777.08
275	19.00	148.56	3.07	33.01	129.56	4.55	6614.69
276	14.50	144.75	3.25	42.91	130.25	4.81	6916.25
277							
278	16.75	132.63	3.08	34.08	115.88	4.56	6108.44
279	15.38	135.25	3.16	36.51	119.88	4.68	6278.75
280	14.75	137.13	3.20	38.79	122.38	4.74	6415.63
281							
282							
283	14.75	138.25	3.20	39.42	123.50	4.74	6483.75
284							
285							
286							
287	16.88	133.38	3.08	33.47	116.50	4.56	6074.38
288	14.70	152.20	3.26	44.61	137.50	4.84	7278.75
289	21.00	142.75	2.95	27.76	121.75	4.37	6087.50
290	16.50	131.25	3.08	35.09	114.75	4.55	5975.00
291							
292	15.00	150.00	3.25	43.54	135.00	4.81	7201.25
293							
294	15.13	138.13	3.19	37.82	123.00	4.72	6435.00
295	17.50	131.25	3.03	32.17	113.75	4.48	5901.25
296	15.50	149.75	3.22	45.75	134.25	4.77	6997.50
297	17.38	132.38	3.05	32.68	115.00	4.51	5975.63
298	16.75	130.00	3.07	32.29	113.25	4.54	5971.25
299	14.42	147.17	3.25	45.07	132.75	4.82	7096.67
317							
318							
319	12.69	152.75	3.36	50.26	140.06	4.98	7543.44
320	14.63	130.88	3.18	37.75	116.25	4.70	6133.13
321	16.00	118.63	3.03	30.51	102.63	4.48	5475.63
322	13.67	127.08	3.21	38.91	113.42	4.75	6098.33
323	14.88	126.38	3.14	35.22	111.50	4.64	5848.13
324	13.88	125.81	3.19	38.09	111.94	4.71	5929.38
325	13.13	125.38	3.22	39.92	112.25	4.76	6087.50
326	13.83	128.92	3.21	39.16	115.08	4.74	6047.09
327	13.83	132.88	3.23	40.42	119.04	4.77	6351.87
328	12.33	131.75	3.30	44.64	119.42	4.87	6350.83
329	12.38	144.69	3.35	48.87	132.31	4.96	7025.31
330	14.13	126.29	3.18	37.33	112.17	4.70	6019.99
331	14.38	123.44	3.15	35.91	109.06	4.65	5702.50
332	14.38	117.25	3.11	33.89	102.88	4.59	5440.63
333	14.13	117.88	3.12	34.06	103.75	4.61	5555.63
334	17.13	123.38	3.01	29.23	106.25	4.45	5324.38
335	12.50	130.00	3.28	44.35	117.50	4.85	6231.25
336	12.65	134.35	3.29	44.32	121.70	4.87	6431.75
337	15.50	124.25	3.10	33.55	108.75	4.59	5698.75

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
338	13.08	146.17	3.32	46.12	133.08	4.92	7113.33
339	15.50	111.13	3.01	29.19	95.63	4.45	5125.63
340	15.50	139.00	3.18	36.71	123.50	4.70	6412.50
341	14.25	124.75	3.16	37.27	110.50	4.67	5976.25
342	15.75	127.25	3.09	35.28	111.50	4.57	5931.25
343	16.58	131.83	3.06	34.48	115.25	4.53	6087.07
344	16.25	127.50	3.07	34.55	111.25	4.54	5800.00
345							
346							
347	27.50	93.00	2.14	13.57	65.50	3.16	3156.25
348	16.25	132.44	3.09	35.18	116.19	4.57	6100.31
349							
350							
351	16.00	129.25	3.08	34.55	113.25	4.56	6018.75
352	16.00	131.00	3.09	34.88	115.00	4.58	6153.75
353							
354	19.50	122.75	2.89	26.92	103.25	4.27	5138.75
355							
357	16.00	140.92	3.15	36.69	124.92	4.66	6546.67
358							
359	17.75	136.00	3.04	31.81	118.25	4.50	6102.50
383	19.00	140.25	3.00	32.06	121.25	4.45	6205.00
384	18.50	138.25	3.03	32.75	119.75	4.49	6130.00
385							
386							
387	15.50	141.00	3.17	39.63	125.50	4.69	6583.75
388	16.50	149.25	3.19	38.69	132.75	4.72	6851.25
389							
390	18.25	143.00	3.06	33.70	124.75	4.53	6403.75
391	16.58	140.50	3.13	36.27	123.92	4.63	6457.08
392	15.25	137.75	3.17	38.88	122.50	4.69	6457.50
393	15.75	143.00	3.17	38.59	127.25	4.70	6718.75
394	16.75	139.13	3.11	35.43	122.38	4.61	6451.25
395	16.75	147.50	3.16	38.93	130.75	4.69	6775.00
397	15.25	154.88	3.25	42.62	139.63	4.82	7290.00
398	16.00	141.25	3.16	37.69	125.25	4.67	6571.25
399	16.67	143.00	3.14	36.79	126.33	4.64	6514.60
400	20.88	143.00	2.94	29.20	122.13	4.36	6070.63
401							
402							
403	20.50	116.58	2.77	24.25	96.08	4.10	5065.42
404							
405	20.69	118.94	2.79	23.90	98.25	4.12	5155.94
406	21.25	121.88	2.78	24.83	100.63	4.12	5245.00
407	22.00	124.08	2.77	23.29	102.08	4.10	5214.98
408	19.58	131.83	2.94	29.00	112.25	4.35	5842.09
409	21.00	121.63	2.78	25.61	100.63	4.12	5197.50
410	19.00	143.13	3.02	32.46	124.13	4.48	6420.00

AOI ID	Sum (4) Band 2	Sum (4) Band3	Sum (4) NDVI	Sum (4) RVI	Sum (4) DVI	Sum (4) SAVI	Sum (4) TVI
411							
412							
413							
414	19.88	126.50	2.89	26.59	106.63	4.27	5604.38
415	20.38	118.88	2.81	24.72	98.50	4.15	5245.63
416							
417							
418							
419	20.63	121.25	2.81	24.25	100.63	4.16	5280.63
420	19.17	125.58	2.91	27.98	106.42	4.30	5677.08
421	20.75	112.50	2.72	23.74	91.75	4.03	4813.13
423							
424							
425							
426	19.67	133.17	2.94	29.28	113.50	4.35	5967.91
427	23.00	128.33	2.75	23.21	105.33	4.08	5314.18
428	21.50	113.88	2.70	23.43	92.38	3.99	4785.00
429							
430	20.50	121.00	2.81	24.84	100.50	4.16	5333.75
431	22.56	114.88	2.66	21.82	92.31	3.93	4781.88
432	20.83	126.50	2.84	25.66	105.67	4.21	5528.75
433	24.75	124.38	2.65	20.85	99.63	3.92	4874.38
446	14.75	139.50	3.21	40.15	124.75	4.75	6641.25
447	15.00	127.00	3.12	35.57	112.00	4.62	5956.25
448	14.92	140.92	3.21	40.98	126.00	4.75	6632.50
449	15.75	132.75	3.12	35.53	117.00	4.62	6182.50
450	16.50	132.63	3.09	33.85	116.13	4.57	6067.50
451	15.75	131.88	3.12	35.05	116.13	4.61	6043.75
452	13.25	141.88	3.29	46.03	128.63	4.87	6918.13
453	13.88	134.38	3.22	42.36	120.50	4.77	6452.50
454	15.50	135.58	3.16	38.19	120.08	4.67	6265.42
455	14.50	131.00	3.19	38.19	116.50	4.72	6300.00
456	13.25	127.75	3.22	41.65	114.50	4.76	6081.25
457	14.75	121.00	3.11	35.36	106.25	4.59	5502.50
594							
595							

Variable	by Variable	R Canola	Count	Signif Prob	R Chickpeas	Count	Signif Prob	R Lentils	Count	Signif Prob	R Wheat	Count	Signif Prob
Yield	181-1	0.42	164	0.0000000218	0.41	129	0.0000012146	0.03	16	0.9126588988	0.36	249	0.0000000031
Yield	181-2	0.13	164	0.1091600196	0.46	129	0.0000000316	-0.01	16	0.9817191105	0.35	249	0.0000000085
Yield	181-3	0.70	164	0.0000000000	0.43	129	0.0000004648	-0.33	16	0.2125940537	0.26	249	0.0000463860
Yield	181NDVI	0.65	164	0.0000000000	-0.38	129	0.0000086851	-0.38	16	0.1440961320	-0.05	249	0.4239078843
Yield	181 RVI	0.63	164	0.0000000000	-0.38	129	0.0000068501	-0.39	16	0.1397704417	-0.09	249	0.1474085590
Yield	181 DVI	0.75	164	0.0000000000	0.17	129	0.0474536669	-0.40	16	0.1242795127	0.12	249	0.0667073774
Yield	181 SAVI	0.65	164	0.0000000000	-0.37	129	0.0000154071	-0.38	16	0.1425289741	-0.05	249	0.4657010150
Yield	181 TVI	0.65	164	0.0000000000	0.23	129	0.0083734205	0.44	16	0.0913813874	0.03	249	0.6462489080
Yield	221-1	0.24	164	0.0023796002	0.19	129	0.0327510968	-0.43	16	0.0986337570	0.00	249	0.9773799000
Yield	221-2	-0.63	164	0.0000000000	0.34	129	0.0000732226	-0.62	16	0.0108644909	-0.11	249	0.0926678347
Yield	221-3	0.84	164	0.0000000000	0.04	129	0.6807729163	0.02	16	0.9349995778	0.23	249	0.0001997702
Yield	221NDVI	0.82	164	0.0000000000	-0.34	129	0.0001011681	0.40	16	0.1256466340	0.17	249	0.0062668093
Yield	221 RVI	0.80	164	0.0000000000	-0.33	129	0.0001671088	0.42	16	0.1083311096	0.12	249	0.0658795455
Yield	221 DVI	0.84	164	0.0000000000	-0.18	129	0.0472951641	0.27	16	0.3177335665	0.22	249	0.0005622046
Yield	221 SAVI	0.82	164	0.0000000000	-0.33	129	0.0001167483	0.40	16	0.1283574435	0.17	249	0.0059411529
Yield	221 TVI	0.83	164	0.0000000000	-0.23	129	0.0097514578	0.27	16	0.3055045410	0.22	249	0.0006161362
Yield	240-1	-0.71	164	0.0000000000	0.36	129	0.0000232964	-0.47	16	0.0645044469	-0.17	249	0.0058066448
Yield	240-2	-0.72	164	0.0000000000	0.30	129	0.0005155414	-0.70	16	0.0026990120	-0.17	249	0.0082016777
Yield	240-3	0.79	164	0.0000000000	-0.06	129	0.5277776502	0.56	16	0.0249883845	0.11	249	0.0869329457
Yield	240NDVI	0.76	164	0.0000000000	-0.26	129	0.0031795594	0.68	16	0.0037005580	0.18	249	0.0050896161
Yield	240 RVI	0.79	164	0.0000000000	-0.20	129	0.0234743852	0.66	16	0.0050293071	0.14	249	0.0258867880
Yield	240 DVI	0.80	164	0.0000000000	-0.17	129	0.0513151908	0.65	16	0.0066888054	0.13	249	0.0354047839
Yield	240 SAVI	0.76	164	0.0000000000	-0.26	129	0.0033586177	0.68	16	0.0037351161	0.18	249	0.0051221084
Yield	240 TVI	0.78	164	0.0000000000	-0.16	129	0.0701779424	0.68	16	0.0036384767	0.13	249	0.0441176327
Yield	251-1	-0.13	155	0.1154048675	0.41	111	0.0000059956	-0.73	16	0.0012050950	-0.30	160	0.0001315198
Yield	251-2	-0.50	155	0.0000000000	0.35	111	0.0001603525	-0.87	16	0.0000118148	-0.32	160	0.0000450555
Yield	251-3	0.85	155	0.0000000000	0.03	111	0.7754813223	0.65	16	0.0061045225	0.09	160	0.2501684394
Yield	251NDVI	0.69	155	0.0000000000	-0.25	111	0.0080775661	0.82	16	0.0000915467	0.31	160	0.0000564344
Yield	251 RVI	0.71	155	0.0000000000	-0.19	111	0.0447331465	0.78	16	0.0003513583	0.28	160	0.0004305241
Yield	251 DVI	0.83	155	0.0000000000	-0.15	111	0.1232434076	0.78	16	0.0003184531	0.15	160	0.0562641032
Yield	251 SAVI	0.70	155	0.0000000000	-0.25	111	0.0085685824	0.82	16	0.0000932451	0.31	160	0.0000633422
Yield	251 TVI	0.82	155	0.0000000000	-0.18	111	0.0661561103	0.81	16	0.0001419806	0.16	160	0.0414010339
Yield	287-1	-0.31	164	0.0000596218	0.43	129	0.0000004450	-0.84	16	0.0000441745	0.15	249	0.0187828167
Yield	287-2	-0.60	164	0.0000000000	0.38	129	0.0000077019	-0.80	16	0.0002177042	0.20	249	0.0014062331
Yield	287-3	0.71	164	0.0000000000	-0.35	129	0.0000435001	0.82	16	0.0001145666	-0.17	249	0.0075000402
Yield	287NDVI	0.69	164	0.0000000000	-0.39	129	0.0000041631	0.77	16	0.0004270515	-0.22	249	0.0005983700
Yield	287 RVI	0.70	164	0.0000000000	-0.32	129	0.0002668054	0.86	16	0.0000174938	-0.20	249	0.0019412397
Yield	287 DVI	0.72	164	0.0000000000	-0.37	129	0.0000195965	0.81	16	0.0001208123	-0.19	249	0.0025194420
Yield	287 SAVI	0.69	164	0.0000000000	-0.39	129	0.0000042595	0.78	16	0.0004192546	-0.22	249	0.0005924694
Yield	287 TVI	0.71	164	0.0000000000	-0.36	129	0.0000319277	0.79	16	0.0002579850	-0.20	249	0.0011589061
Yield	320-1	0.09	164	0.2783344571	0.21	129	0.0174414529	-0.62	16	0.0097597672	0.44	249	0.0000000000
Yield	320-2	0.68	164	0.0000000000	0.26	129	0.0031023268	-0.68	16	0.0036192766	0.48	249	0.0000000000
Yield	320-3	0.04	164	0.6378248881	-0.08	129	0.3502812600	0.81	16	0.0001459468	-0.21	249	0.0006845959
Yield	320NDVI	-0.36	164	0.0000020724	-0.19	129	0.0306494960	0.72	16	0.0015839838	-0.48	249	0.0000000000
Yield	320 RVI	-0.38	164	0.0000007336	-0.26	129	0.0030959149	0.76	16	0.0006131533	-0.45	249	0.0000000000
Yield	320 DVI	-0.20	164	0.0117986298	-0.14	129	0.1219659937	0.79	16	0.0003136368	-0.41	249	0.0000000000

Appendix J: Pairwise Correlation Results for Yield and Satellite Parameters

Variable	by Variable	R Canola	Count	Signif Prob	R Chickpeas	Count	Signif Prob	R Lentils	Count	Signif Prob	R Wheat	Count	Signif Prob
Yield	320 SAVI	-0.36	164	0.0000024209	-0.19	129	0.0312814413	0.72	16	0.0015554681	-0.48	249	0.0000000000
Yield	320 TVI	-0.43	164	0.0000000094	-0.16	129	0.0672345195	0.77	16	0.0004671867	-0.45	249	0.0000000000
Yield	Sum Band 1	-0.11	155	0.1716971012	0.45	111	0.0000008070	-0.87	16	0.0000107058	0.04	160	0.5890358393
Yield	Sum Band 2	-0.51	155	0.0000000000	0.44	111	0.0000011347	-0.89	16	0.0000037593	0.04	160	0.6494437545
Yield	Sum Band3	0.85	155	0.0000000000	-0.04	111	0.6647442169	0.84	16	0.0000518893	0.25	160	0.0017454163
Yield	Sum NDVI	0.80	155	0.0000000000	-0.34	111	0.0002366422	0.87	16	0.0000138717	0.09	160	0.2508013856
Yield	Sum RVI	0.81	155	0.0000000000	-0.27	111	0.0041265514	0.88	16	0.0000061289	0.21	160	0.0087960361
Yield	Sum DVI	0.85	155	0.0000000000	-0.22	111	0.0214196541	0.86	16	0.0000209647	0.21	160	0.0090965317
Yield	Sum SAVI	0.80	155	0.0000000000	-0.34	111	0.0002756104	0.87	16	0.0000141326	0.09	160	0.2323410545
Yield	Sum TVI	0.84	155	0.0000000000	-0.24	111	0.0120016916	0.86	16	0.0000211130	0.18	160	0.0248860024
Yield	Sum (5) Band 1	-0.34	155	0.0000158933	0.39	111	0.0000232677	-0.86	16	0.0000169287	-0.07	160	0.4091073247
Yield	Sum (5) Band 2	-0.63	155	0.0000000000	0.37	111	0.0000610492	-0.88	16	0.0000072250	-0.06	160	0.4186831983
Yield	Sum (5) Band3	0.85	155	0.0000000000	-0.11	111	0.2661215037	0.84	16	0.0000379713	0.18	160	0.0217567456
Yield	Sum (5) NDVI	0.80	155	0.0000000000	-0.30	111	0.0011388014	0.86	16	0.0000162175	0.10	160	0.2086042033
Yield	Sum (5) RVI	0.81	155	0.0000000000	-0.26	111	0.0065598840	0.88	16	0.0000066684	0.22	160	0.0062994085
Yield	Sum (5) DVI	0.85	155	0.0000000000	-0.23	111	0.0170144560	0.86	16	0.0000211249	0.18	160	0.0264804640
Yield	Sum (5) SAVI	0.80	155	0.0000000000	-0.30	111	0.0012045503	0.86	16	0.0000163752	0.10	160	0.1989587027
Yield	Sum (5) TVI	0.84	155	0.0000000000	-0.25	111	0.0090383103	0.86	16	0.0000216288	0.16	160	0.0388873915
Yield	Sum (4) Band 1	-0.39	155	0.0000006396	0.43	111	0.0000019827	-0.84	16	0.0000508476	-0.21	160	0.0075958086
Yield	Sum (4) Band 2	-0.70	155	0.0000000000	0.39	111	0.0000188867	-0.89	16	0.0000038285	-0.21	160	0.0073352767
Yield	Sum (4) Band3	0.85	155	0.0000000000	-0.13	111	0.1753832807	0.83	16	0.0000663609	0.22	160	0.0046446760
Yield	Sum (4) NDVI	0.80	155	0.0000000000	-0.32	111	0.0006369995	0.86	16	0.0000221682	0.25	160	0.0017149678
Yield	Sum (4) RVI	0.81	155	0.0000000000	-0.26	111	0.0056639854	0.89	16	0.0000051890	0.23	160	0.0032610180
Yield	Sum (4) DVI	0.84	155	0.0000000000	-0.25	111	0.0088358075	0.86	16	0.0000178177	0.25	160	0.0017539401
Yield	Sum (4) SAVI	0.80	155	0.0000000000	-0.32	111	0.0006764744	0.86	16	0.0000221704	0.25	160	0.0016446184
Yield	Sum (4) TVI	0.84	155	0.0000000000	-0.26	111	0.0058472711	0.85	16	0.0000256924	0.25	160	0.0017450940