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Global Agro-Ecological Zones Assessment: Methodology and Results

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Interim Report

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Global Agro-Ecological Zones Assessment: Methodology and Results

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Foreword

The collaboration between the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA) goes back more than twenty years, when FAO started a joint project on Land Resources for the Populations of the Future, completed in 1984. Since then, a number of collaborative programmes were undertaken to underpin perspective studies that allowed prediction and estimates on how agriculture would develop towards the 21st century, and where problems were most likely to develop for achieving food security, particularly in developing countries. Those estimates, which are currently being revisited and extended in FAO's study "Agriculture towards 2015/30", have proved to be quite accurate, widely quoted and appreciated..

Originating from an internationally accepted Framework for Land Evaluation, the Agro-ecological Zones (AEZ) methodology enables rational land management options to be formulated on the basis of an inventory of land resources and evaluation of biophysical limitations and potentials. The recent enhanced availability of digital global databases of climatic parameters, topography, soil and terrain, land cover, and population distribution has now enabled revisions and improvements in AEZ calculation procedures. Also, these data have facilitated expansion of AEZ crop suitability and land productivity assessments to temperate and boreal environments, resulting in a global coverage for assessments of agricultural potentials.

A major challenge facing any scientific analysis of complex societal issues is the communication of research results in a way that provides policy makers and the public with helpful and reliable insights. The IIASA Land Use Project has developed, in cooperation with FAO, a CD-ROM application to take advantage of the new ways of communication offered by the electronic media. The hyperlinked document presents the methodology and global data sets applied in the assessment and demonstrates the regional potentials and limitations of land and biological resources. It also discusses various agricultural issues related to regional food security and sustainable resource development.

The CD-ROM begins to address several key resource questions: Will there be sufficient land for agricultural production to meet food and fiber demands of future populations? Where are shortages of agricultural land, and where there is room for agricultural expansion? What contribution can be expected from irrigation? Is land under forest ecosystems potentially good agricultural land? What are the main physical constraints to agricultural production? Will global warming affect agricultural potentials?

It is hoped that the massive amount of analyzed information gathered and presented here, will contribute significantly to a sound use of scarce land resources, and to enhanced food security for all.

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FAO, Rome, November, 2000

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Abstract

Over the past twenty years, the term *agro-ecological zones methodology* (AEZ) has become widely used. However, it has been associated with a wide range of different activities that are often related yet quite different in scope and objectives. FAO and IIASA differentiate the AEZ methodology in the following activities:

First, AEZ provides a standardized framework for the characterization of climate, soil and terrain conditions relevant to agricultural production. In this context, the concepts of Length of Growing Period (LGP) and of latitudinal thermal climates have been applied in mapping activities focussing on zoning at various scales, from sub-national to global level. Second, AEZ matching procedures are used to identify crop-specific limitations of prevailing climate, soil and terrain resources, under assumed levels of inputs and management conditions. This part of the AEZ methodology provides estimates of maximum potential and agronomically attainable crop yields for basic land resources units. Third, AEZ provides the frame for various applications. The previous two sets of activities result in very large databases. The information contained in these data sets form the basis for a number of AEZ applications, such as quantification of land productivity, extents of land with rain-fed or irrigated cultivation potential, estimation of the land's population supporting capacity, and multi-criteria optimization of land resources use and development.

The AEZ methodology utilizes a land resources inventory to assess, for specified management conditions and levels of inputs, all feasible agricultural land-use options and to quantify expected production of cropping activities relevant in the specific agro-ecological context. The characterization of land resources includes components of climate, soils and landform. Recent availability of digital global databases of climatic parameters, topography, soil and terrain, and land cover has allowed for revisions and improvements in calculation procedures and to expand assessments of AEZ crop suitability and land productivity potentials to temperate and boreal environments. This effectively enables global coverage for assessments of agricultural potentials.

The AEZ methodologies and procedures have been extended and newly implemented to make use of these digital geographical databases, and to cope with the specific characteristics of growing periods in the seasonal temperate and boreal climates. This report describes the methodological adaptations necessary for the global assessment and illustrates with numerous results a wide range of global AEZ applications.

Executive Summary

Background

Land is an indispensable resource for the most essential human activities: it provides the basis for agriculture and forest production, water catchment, recreation, and settlement. The range of uses that can be made of land for human needs, is limited by environmental factors including climate, topography and soil characteristics, and is to a large extent determined by demographic, socioeconomic, cultural, and political factors, such as population density, land tenure, markets, institutions, and agricultural policies.

The Food and Agriculture Organization of the United Nations (FAO) with the collaboration of the International Institute for Applied Systems Analysis (IIASA), has developed a system that enables rational land use planning on the basis of an inventory of land resources and evaluation of biophysical limitations and potentials. This is referred to as the Agro-Ecological Zones (AEZ) methodology.

Recent availability of digital global databases of climatic parameters, topography, soil and terrain, vegetation, and population distribution has called for revisions and improvements in calculation procedures and in turn has allowed for expanding assessments of AEZ crop suitability and land productivity potentials to temperate and boreal environments.

Methodology

The AEZ methodology follows an environmental approach; it provides a standardized framework for the characterization of climate, soil and terrain conditions relevant to agricultural production. Crop modeling and environmental matching procedures are used to identify crop-specific limitations of prevailing climate, soil and terrain resources, under assumed levels of inputs and management conditions. This part of the AEZ methodology provides maximum potential and agronomically attainable crop yields for basic land resources units (usually grid-cells in the recent digital databases).

The AEZ computations were completed for a range of climatic conditions, including a reference climate (average of period 1961-1990), individual historical years of 1960 to 1996, and scenarios of future climate based on the published outputs of various global climate models. Hence, the AEZ results consistently quantify impacts on land productivity of historical climate variability as well as of potential future climate change.

The FAO/Unesco Digital Soil Map of the World (DSMW) has been made the reference for constructing a land surface database comprising of more than 2.2 million grid-cells at 5' latitude/longitude within a raster of 2160 rows and 4320 columns. On the input side, the key components of the database applied in AEZ include the FAO DSMW and linked soil association and attribute tables, a slope distribution database, and a layer providing distributions in terms of eleven aggregate land-cover classes derived from a global 1 km seasonal land cover data set. On the output side, many new data sets have been compiled at

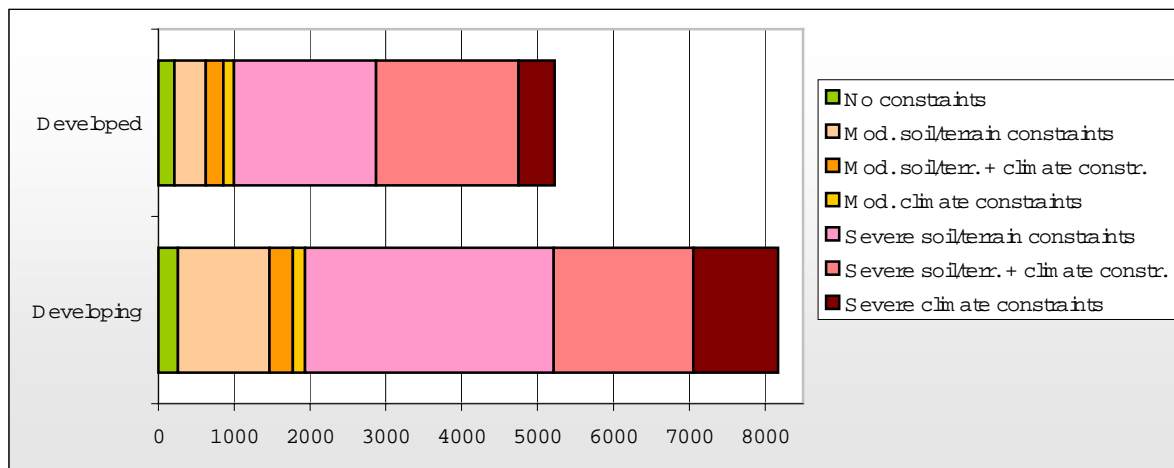
grid-cell level and have been tabulated at country and regional level, including general agro-climatic characterizations of temperature and moisture profiles, and time-series of attainable crop yields for major food and fiber crops.

The information contained in these data sets forms the basis for several further AEZ applications. Examples are: the quantification of land productivity, the estimation of extents of land with rain-fed or irrigated cultivation potential, the occurrences of environmental constraints to agricultural production, the identification of potential ‘hot spots’ of agricultural conversion, and the possible geographical shifts of agricultural land potentials as result of changing climate. Finally, the results of AEZ land productivity assessments provide a spatially explicit and agronomically sound basis for applications of multi-criteria optimization of land resources use and development.

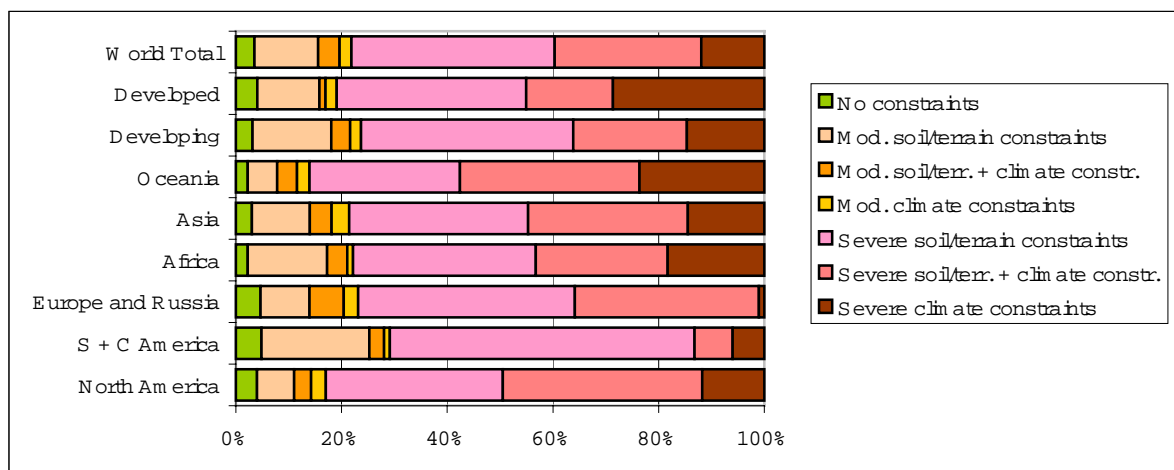
Findings

In the 1998 Revision, the United Nations medium variant population projection indicates an increase of world population to about 8.9 thousand million by the year 2050, with a possible range of 7.3 to 10.7 thousand million. Most experts agree that through full and adequate application of modern agricultural technology, the world's land resources could provide sufficient food, fiber, animal feed, biofuel and timber for such a world population. In practice, however, there will very likely be acute land shortages in some regions, especially in several developing countries. The AEZ procedures and applications have been used to provide an up-to-date environmental assessment of global food and fiber prospects.

1. The AEZ results confirm that the Earth’s land, climate and biological resources are sufficient to meet the needs of food and fiber of future generations, and more in particular for a world population of 8.9 thousand million, as projected for the year 2050 by the UN medium variant.
2. Despite this affirmative aggregate picture, there are also reasons for profound concerns. Several regions exist, where the rain-fed cultivation potential has already been exhausted, as for example is the case in parts of Asia. Land degradation, if continuing unchecked, may exacerbate regional land scarcities. Concerns for the environment may prevent some resources from being developed for agriculture. Global warming may alter the condition and distribution of land suitable for cropping. In addition, socioeconomic development may infringe on the current agricultural resource base for want of rapidly expanding industrial and service sectors.
3. On the basis of currently available global soil, terrain and climate data, the AEZ approach estimates that 10.5 thousand million hectares of land, i.e., more than three-quarters of the global land surface (excluding Antarctica), suffer rather severe constraints for rain-fed crop cultivation. Some 13 percent is too cold, 27 percent is too dry, 12 percent is too steep, and about 65 percent are constrained by unfavorable soil conditions (multiple constraints coinciding in some locations).



Extents of land with climate and soil/terrain constraints



Distribution of climate and soil/terrain constraints by region

4. Various ways are available for estimating the extent of land with cultivation potential for rain-fed crops. Any quantification depends on a variety of assumptions: the range of crop types considered, the definition of what level of output qualifies as acceptable, the social acceptance of land-cover conversions (in particular of forests), and the assumptions on what land constraints may be alleviated with modern inputs and investment. Hence, our estimates range from 1.3 thousand million ha (land very suitable and suitable for major cereal crops, under high inputs and mechanization, outside current forest areas) to 3.3 thousand million ha (land very suitable, suitable or moderately suitable for at least one of the AEZ crop types, within or outside current forest areas). The results presented in this study are based on the following calculation procedures for each grid-cell:

- (1) Determine all land very suitable and suitable at high level of inputs for the crops offering the largest total extent;
- (2) Of the balance of land after (1), determine all land very suitable, suitable or moderately suitable at intermediate level of inputs for the crops offering the largest extent, and

- (3) Of the balance of land after (1) and (2), determine all suitable land (i.e. very suitable, suitable, moderately suitable or marginally suitable) at low level of inputs for the crops offering the largest extent.

The total extents obtained in this way for each grid-cell, referred to as mixed level of inputs, were calculated for rain-fed and rain-fed plus irrigated conditions. When considering all modeled Global AEZ crop types (excluding silage maize, forage legumes and grasses), mixing all three input levels, and assuming no restrictions for land-cover conversion, we conclude that about one-quarter of the global land surface (excluding Antarctica) can be regarded as potentially suitable for crop cultivation. In developed countries about one-fifth comprises of land with rain-fed cultivation potential. In developing countries it amounts to about 28 percent. This estimate, based on a rather generous definition of land with cultivation potential, is twice the area estimated as actually in use for cultivation in 1995-97 (FAO, 2000; Table 4.7, p. 104).

Region	Total Land	Land with cultivation potential		Housing, Infrastr.	Not suitable
		Total	Under forest		
North America	2138	384	135	9	1637
South & Central America	2049	858	346	16	1048
Europe and Russia	2259	511	97	21	1645
Africa	2990	939	132	26	1909
Asia	3113	516	47	83	2407
Oceania	850	116	17	1	694
Developing	8171	2313	527	124	5383
Developed	5228	1012	247	33	3956
World Total	13400	3325	774	156	9338

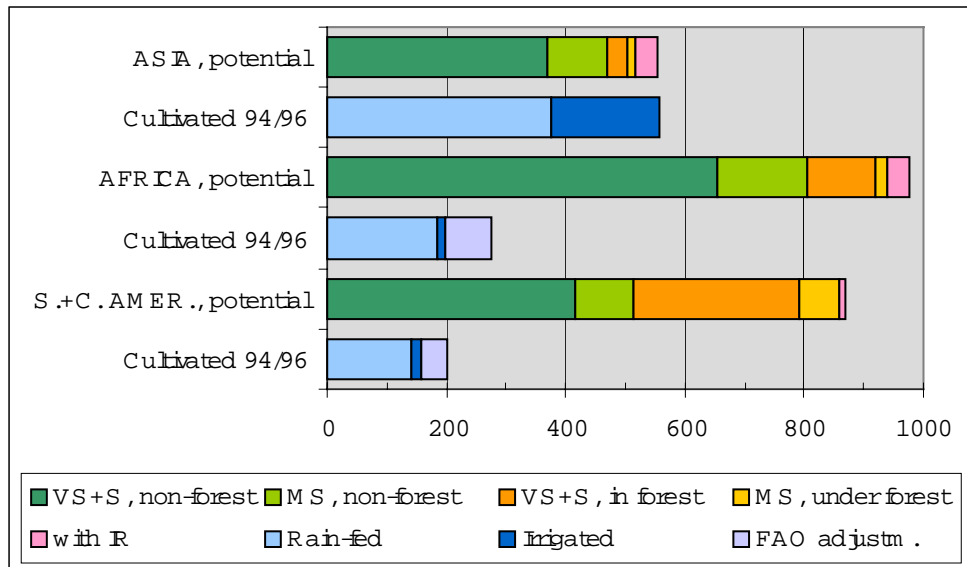
Land with rain-fed cultivation potential for major food and fiber crops (million ha)

Nevertheless, there are several regions where the rain-fed cultivation potential is nearly fully exhausted or has already been exceeded. If forests were to be maintained, then less than 2.55 thousand million ha would qualify as land with cultivation potential, of which 1.94 thousand million ha are adjudged very good or good suitability.

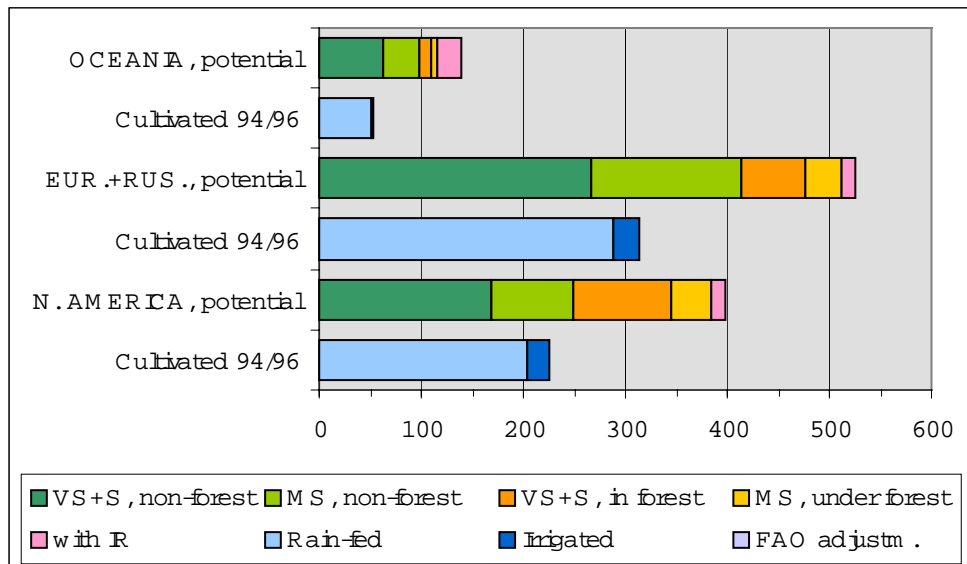
Region	Rain-fed cultivated land 1994-96	Land with good cultivation potential		Land with moderate cultivation potential	
		Total	Under forest	Total	Under forest
North America	203	266	96	118	39
South & Central America	141	698	281	161	65
Europe and Russia	289	329	61	183	35
Africa	185	767	114	172	18
Asia	376	406	36	110	11
Oceania	50	75	12	40	5
Developing	702	1871	433	441	94
Developed	543	669	168	343	79
World Total	1245	2541	601	784	174

Rain-fed cultivated land in 1994-96 (Source: FAOSTAT) and suitability of rain-fed cultivation potential for major food and fiber crops (million ha)

5. Despite recognizing that statistics of land in cultivation are likely to be underestimating actual use in developing countries by some 10 to 20 percent (see FAO, 2000), the Global AEZ results indicate that there is still a significant potential for conversion to arable use in Africa and South America, including from current forest areas. In other regions this potential is either exhausted (e.g., Asia) or unlikely to be exploited for agriculture under current and expected future conditions (i.e., Europe, North America and Oceania).



Comparison of land with crop production potential and land used for cultivation in 1994-96 (million ha) in developing regions



Comparison of land with crop production potential and land used for cultivation in 1994-96 (million ha) in developed regions

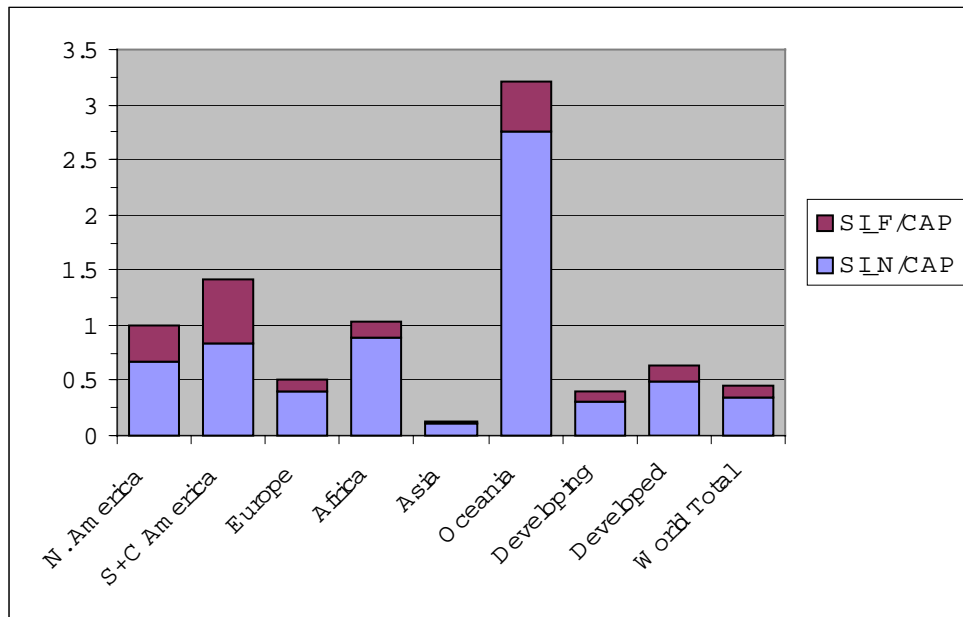
VS = very suitable, S = suitable, MS = moderately suitable

6. By looking at the full range of crop types, without consideration of the demand for different products, we may over-estimate the useful extents of land with cultivation potential. When restricting the considered crop types to the three major cereals, namely wheat, rice, and grain-maize, and allowing for nonagricultural land uses, an estimate of about 2.4 thousand million ha of land with rain-fed cultivation potential was obtained. Of these, 1.5 thousand million ha were found in developing countries and 0.9 thousand million ha in developed regions.

Region	Total Land	Land with good cultivation potential		Land with moderate cultivation potential	
		Total	Under forest	Total	Under forest
North America	2138	235	82	107	33
South & Central America	2049	283	128	191	72
Europe and Russia	2259	282	41	181	35
Africa	2990	404	25	188	18
Asia	3113	263	14	121	11
Oceania	850	44	7	29	4
Developing	8171	1076	166	498	100
Developed	5228	565	132	319	72
World Total	13400	1612	298	817	172

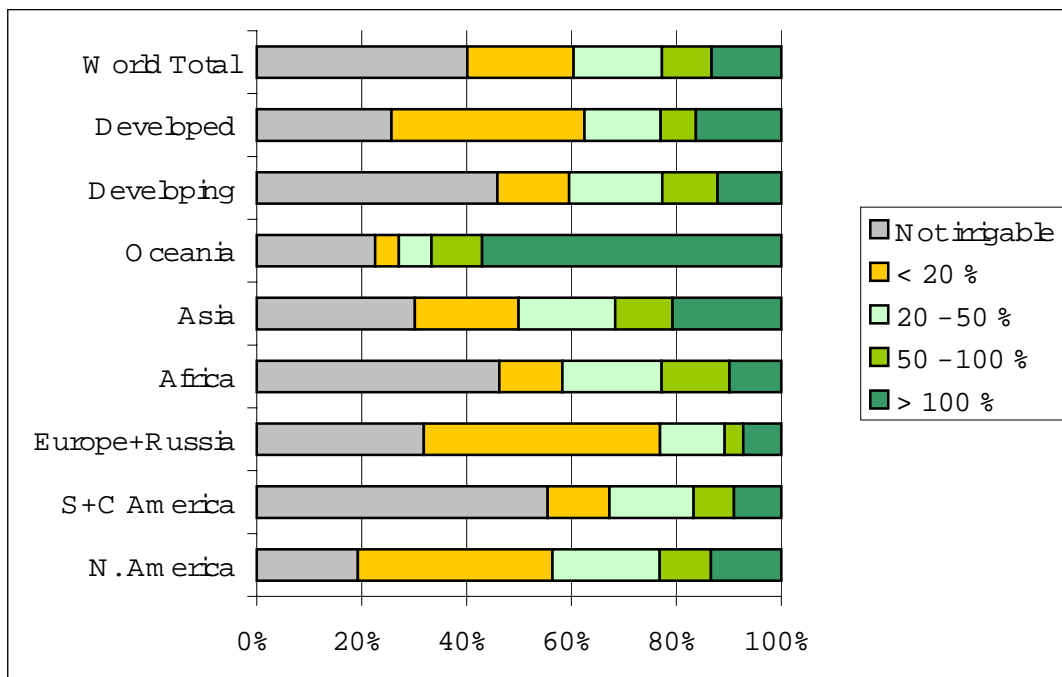
Land with rain-fed cultivation potential for wheat, rice or grain-maize (million ha)

7. Combining AEZ results with spatial land cover data, the extent of land with cultivation potential presently under forest ecosystems was estimated. About 237 million hectares of the area classified as forest ecosystems was assessed as very suitable or suitable for cultivation of wheat, rice or grain-maize at high level of inputs. On the other hand, the analysis shows that globally almost 85 percent of forest ecosystems are considered not suitable or at best marginally suitable for cereal cultivation.
8. The study highlights the uneven distribution of land and climate resources. We use population estimates of 1995 and a suitability index SI (a weighted sum of different land suitability classes optimizing over all AEZ food crops and for mixed input levels) to compare availability of land with crop cultivation potential across regions, both with and without consideration of areas classified as dominantly forests. SI_N and SI_F refer respectively to the index numbers calculated for areas outside and within forest areas. For total availability (SI_N plus SI_F) the world average is 0.45 suitability index units per person, ranging between 0.12 units in Asia to 3.2 units in Oceania.



Per capita availability of land with crop cultivation potential (SI units/person)

9. Assuming availability of water resources, but limiting the analysis to soil conditions indicating presence of water (such as Gleysols and Fluvisols), some 65 million hectares, i.e., only about 1.8 percent of arid and hyper-arid zones, were assessed as prime land for cereals under irrigation, which in turn equates to less than 3 percent of total prime land for cereals. The results suggest that irrigation is more important in providing stable water supply in areas of climatic variability rather than for bringing land in hyper-arid and arid regions into cultivation.



Distribution of land with cultivation potential by irrigation impact classes, showing increase in potential output with full exploitation of irrigation.

Full exploitation of all potential irrigable land would increase the global gross extent of suitable land for cereals by 6 to 9 percent. The impact of irrigation is more pronounced on the increase of potential production than on potential area. The global cereal production potential would increase by 30 to 40 percent.

10. The application of a set of temperature and rainfall sensitivity scenarios revealed a modest increase of cultivable rain-fed land for temperature increases up to 2°C on global scale. With a higher temperature increase alone, extents of cultivable rain-fed land start to decrease. When both temperature and rainfall amounts increase, the extents of cultivable rain-fed land increase steadily. For example, a temperature increase of 3°C paired with a rainfall increase of 10 percent would lead globally to about 4 percent more cultivable rain-fed land. In the developed countries this increase is even markedly higher; it exceeds 25 percent. Contrariwise, for developing countries there would be a decrease of 11 percent.

Limitations of the study

The Global AEZ results presented are based on a half-degree latitude/longitude world climate data set, 5' soils data derived from the digital version of the FAO Soil Map of the World, the 1 km Global Land Cover Characteristics Database, and a 30 arc-second digital elevation data set. While representing the most recent global data compilations, the quality and reliability of these data sets is known to be uneven across regions. Especially the quality of the world soil map is reason for concern. It is based on a 1:5,000,000 scale map and it is generally accepted that its reliability may vary considerably between different areas. At present substantial improvements to the soil information is in progress and several regional updates were published recently.

Another issue is that the current status of land degradation cannot be inferred from the FAO Soil Map of the World. The only study available with global coverage, the Global Assessment of Soil Degradation (GLASOD) offers insufficient detail and quantification for useful application within Global AEZ.

Socioeconomic needs of rapidly increasing and wealthier populations are the main driving force in the allocation of land resources to various kinds of uses, and socioeconomic considerations are crucial for rational planning of sustainable agricultural development. So far, in Global AEZ the use of socioeconomic information is limited to two elements: spatial distribution of population, and the definition of modes of production and the quantification of 'input-output packages'. The latter are referred to as the land utilization types, taking, to some extent, into account the socioeconomic context of production decisions and conditions.

For the above reasons, the results obtained from this Global AEZ study should be treated in a conservative manner at appropriate aggregation levels, which are commensurate with the resolution of basic data and the scale of the study.

While various modes have been pursued for “ground-truthing” and verifying results of the Global AEZ suitability analysis, there is a need for further validation of results and underlying databases

Next steps

The present study has outlined various applications, where biophysical assessments based on AEZ can substantially contribute. While improvement of the basic methodology and data is a

general aim, the planned work is concerned with regional applications and case studies. Several activities related to Agro-ecological Zones are currently under way or under consideration:

- An AEZ application dealing with the impacts of climate variability and climate change on agricultural production on global scale. In this, we intend to include water resources data and modeling to enhance the assessment of irrigation production potentials at watershed level.
- A CD-ROM dealing with various data sets including results of AEZ applications generated by IIASA's Land Use Change Project (LUC) covering the Former Soviet Union, Mongolia and China at a 5 km resolution grid. This CD-ROM will also include an AEZ application for forestry, i.e., for biomass plantation forestry, traditional forestry, and conservation forestry.
- Specific AEZ studies for so-called "hot spots" with special reference to the effect of climatic variability on food security. Proposed study areas are: Horn of Africa, (IGADD countries). Southern Africa (Zimbabwe, Mozambique, South Africa), Bangladesh, and China. Because of limited availability of ground data for the Africa studies, we will to a large extent rely on historical remote sensing data, such as AVHRR and LANDSAT data.
- Using results of the present study by FAO and IIASA and other institutions for linking with agricultural, demographic and socio-economic statistics.

It is expected that the Global AEZ basic suitability procedures and model parameters will benefit from scrutiny and updating while routinely used or as result of newly developed applications.

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Acronyms and Abbreviations

AEZ	Agro-Ecological Zones
ALES	Automated Land Evaluation System
ASSOD	Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia
AVHRR	Advanced Very High Resolution Radiometer
AWC	Available Water-holding Capacity
C ₃	Plants with a 3-carbon organic acid photosynthesis pathway
C ₄	Plants with a 4-carbon organic acid photosynthesis pathway
CABI	Commonwealth Agricultural Bureau International (UK)
CGCM1	Canadian Global Coupled Model
CGIAR	Consultative Group on International Agricultural Research
CHARM	Climate and Human Activities- sensitive Runoff Model - IIASA
CIAT	International Centre for Tropical Agriculture (CGIAR, Colombia)
CIESIN	Center for International Earth Science Information Network
CRES	Centre for Resources and Environmental Studies
CROPWAT	Computer Program for Irrigation planning and management. FAO, Land and Water Development Division.
CRU	Climate Research Unit, University of East Anglia, U.K.
CSD	Commission on Sustainable Development (UN)
DDC	Data Distribution Center
DEM	Digital elevation model
DSMW	Digital Soil Map of the World (FAO)
ECHAM4	Climate model developed at the German Climate Research Centre, Max-Planck Institute for Meteorology, Hamburg, Germany
EMAP	Environmental Monitoring and Assessment Program
ENRIN	Environment and National Resources Information Network
EPA	Environmental Protection Agency (USA)
EPIC	Erosion Productivity Impact Calculator
EROS	Earth Resource Observation System
ERS	Economic Research Service (USDA, USA)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations, Rome, Italy
FAOCLIM	World-wide Agroclimatic Database. Agrometeorology Series Working Paper No. 11, FAO, Rome
FAOSTAT	Food and Agriculture Organization of the United Nations (FAO) Statistical Databases
FESLM	Framework for Evaluating Sustainable Land Management
GAEZ	Global Agro-Ecological Zones
GCM	General Circulation Models
GCOS	Global Climate Observing System

GEF	Global Environmental Facility
GEMS	Global Environmental Monitoring System
GEO	Global Environment Outlook
GIS	Geographical Information System
GLASOD	Global Assessment of the Status of Human-induced Soil Degradation
GLCC	Global Land Cover Characteristics 1-KM Database (EROS Data Center, 2000)
GOOS	Global Ocean Observing System
GRASS	Geographic Resources Analysis Support System
GRID	Global Resource Information Data Base
GRT	Gross Registered Tonnage
GTOPO30	30-arc second digital elevation model
GTOS	Global Terrestrial Observing System
HADCM2	Hadley Centre Climate Prediction and Research Model, U.K.
IBSRAM	International Board for Soil Resources and Management (Thailand)
ICRAF	International Center for Research in Agroforestry (CGIAR, Kenya)
ICRISAT	International Crops Research Institute for the Semi-arid Tropics (CGIAR, India)
ICSU	International Council of Scientific Unions
IDRC	International Development Research Centre (Canada)
IFPRI	International Food Policy Research Institute (CGIAR, USA)
IGADD	Inter-Governmental Authority on Drought and Development
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimensions of Global Environmental Change Programme
IIASA	International Institute for Applied Systems Analysis, Laxenburg, Austria
IIED	International Institute for Environment and Development (UK)
IISD	International Institute for Sustainable Development (Canada)
IITA	International Institute of Tropical Agriculture (CGIAR, Nigeria)
IJC	International Joint Commission (EPA, USA)
ILO	International Labour Office (UN)
ILRI	International Institute for Land Reclamation and Improvement (Netherlands)
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change (WMO/UNEP)
ISCO	International Soil Conservation Organization
ISIS	ISRIC Soil Information System
ISRIC	International Soil Reference and Information Centre, Wageningen, The Netherlands
ISSS	International Society of Soil Science
ITC	International Institute for Aerospace Survey and Earth Sciences (Netherlands)
ITE	Institute of Terrestrial Ecology (UK)
IUCN	World Conservation Union
JRC	Joint Research Centre of the European Commission
LAI	Leaf area index
LANDSAT	Earth Observation Satellites
LQI	Land Quality Indicators
LUC	Land Use Change Project (IIASA)
LUCC	Land-Use and Land-Cover Change (IGBP/IHDP)
LUT	Land utilization type
MCS	Monitoring, Control and Surveillance LGP Length of growing period
MPI	Max Planck Institute for Meteorology, Hamburg, Germany

MSY	Maximum Sustainable Yield
NASA	National Aeronautics and Space Administration (USA)
NGO	Non-governmental Organization
NOAA	National Oceanic and Atmospheric Administration (USA)
NOVIB	Netherlands Organization for International Development Corporation
NRCS	Natural Resources Conservation Service (USA)
OECD	Organization for Economic Cooperation and Development
PSR	Pressure-State-Response
RIVM	National Institute for Public Health and the Environment (Netherlands)
RMD	Resource Management Domain
SARD	Sustainable Agriculture and Rural Development
SCOPE	Scientific Committee on Problems of the Environment
SI	Sustainability Indicator
SOTER	Global and National Soils and Terrain Digital Database
SRS	Sustainability Reference Systems
TR	Thermal Regime
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial and Development Organization
UNL	University of Nebraska-Lincoln
USDA	United States Department of Agriculture
USGS	US Geological Survey
USLE	Universal Soil Loss Equation
WAICENT	World Agricultural Information Centre (FAO)
WASWC	World Association of Soil of Water Conservation
WB	World Bank
WCED	World Commission on Environment and Development
WISE	World Inventory of Soil Emissions Potentials
WMO	World Meteorological Organization (UN)
WOCAT	World Overview of Conservation Approaches and Technologies
WRI	World Resources Institute (USA)
WWF	World Wide Fund for Nature

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Global Agro-Ecological Zones Assessment: Methodology and Results¹

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Harrij van Velthuisen
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1. INTRODUCTION

1.1 Background

In the 1998 Revision, the United Nations medium variant population projection indicates an increase of world population to about 8.9 billion by the year 2050 (United Nations, 1998), with a possible range of 7.3 to 10.7 billion. Most experts agree that through full and adequate application of modern agricultural technology, the world's land resources could provide sufficient food, fiber, animal feed, biofuel and timber for such a world population. In practice, however, there will very likely be acute land shortages in some countries, especially in several developing countries (Fischer and Heilig, 1997).

Land use is largely conditioned by environmental factors including climate, topography and soil characteristics, and it depends on demographic, socioeconomic, cultural, and political factors, such as population pressure, land tenure, markets and agricultural policies. Land is an indispensable resource for the most essential human activities: it provides the basis for agriculture, energy and timber production, water catchment, recreation, and settlement.

In most developing countries, the needs and demands of rapidly increasing populations have been the principal driving force in the allocation of land resources to various kinds of uses, with food production as the primary land use. Population pressure and the increased competition among different land users have emphasized the need for more effective land-use planning and policies. Rational and sustainable land use is an issue of great concern to governments and to land users interested in preserving the land resources for the benefit of present and future populations. Policy-makers and land users face two basic challenges: the need to reverse trends of land degradation in already cultivated areas by improving conditions and re-establishing their level of fertility; and to prevent the degradation of land resources in new development areas through appropriate allocation and adequate use of these resources to maintain productivity and minimize soil erosion. In both cases an integrated approach to planning and management of land resources is a key factor to implementing solutions, which will ensure that land is allocated to uses providing the greatest sustainable benefit.

¹ An electronic version of this document is available from the LUC Project Web-site at IIASA:
<http://www.iiasa.ac.at/Research/LUC>

The increasing human population in developing countries is putting pressure on their finite land resources, sometimes causing over-exploitation and land degradation. Sectoral and single objective approaches to alleviate this situation have frequently not been effective, and an integrated approach is required that involves all stakeholders, accommodates the qualities and limitations of each land unit, and produces viable land use options (FAO, 1995a).

In order to enable rational land use planning, an inventory of land resources and evaluation of its biophysical limitations and constraints are required. This has long been recognized by the Food and Agriculture Organization of the United Nations (FAO). Starting in 1976, the FAO, with the collaboration of the International Institute for Applied Systems Analysis (IIASA), has developed and applied the Agro-ecological Zones (AEZ) methodology, supporting databases and software packages.

1.2 Agro-Ecological Zones approach

Basic principles to be observed in sound land evaluation were first put forward in the 1970s. In 1976 FAO published *A Framework for Land Evaluation* (FAO, 1976a). The Framework defines land units in terms of their characteristics (measurable factors such as slope, soil texture, rainfall, etc.), and qualities (effects such as temperature regime, moisture availability, which result from a combination of characteristics), matches them with potential uses in terms of the requirements of such uses, and then rates the land in terms of suitability for the use. Also, a land use could not be rated as suitable unless it was sustainable. The Framework, and a number of subsequent publications, provide fairly exhaustive lists of land characteristics and land qualities (FAO, 1984b; FAO, 1985; FAO/IIASA, 1991). In a first main application, the methodology was applied to assessing the production capacity of lands in the developing world (FAO/IIASA/UNFPA, 1982). While this assessment was severely limited by the availability and quality of data and the rather poor capability, at that time, to compile and process spatial data sets by computer, the importance of such work for development was recognized by the 1983 FAO Conference. Consequently, the approach was further developed in a case study concerned with the development and implementation of a national level methodology for the determination of land use potentials in Kenya, as a tool for policy formulation and development planning (FAO/IIASA, 1991). The specific role of this policy tool can be defined as assisting in the planning of sectors and regions, bridging the gap between conventional macro-planning and specific project planning.

The AEZ methodology utilizes a land resources inventory to assess, for specified management conditions and levels of inputs, all feasible agricultural land-use options and to quantify expected production of cropping activities relevant in the specific agro-ecological context. The characterization of land resources includes components of climate, soils and landform, which are basic for the supply of water, energy, nutrients and physical support to plants. On the basis of this agronomic evaluation, and using available socioeconomic data to formulate constraints, targets and production options, the attainment of spatial resource allocation objectives can be optimized (Fischer *et al.*, 1998).

The concept of AEZ climatic resources inventories, as described in FAO (1978-81a), has been applied in many continental, regional and country-level studies. Most of these studies were conducted in tropical and subtropical environments. Only a few attempts have been undertaken to extend AEZ applications to temperate, boreal and polar environments (e.g., Stewart, 1983; van Velthuisen and Kassam, 1983; Verheye *et al.*, 1987; UNDP/SSTC/FAO/SLA, 1994). The approaches proposed in these studies diverge owing to differences in specific purpose, prevailing climatic conditions, data availability and scales.

Recent availability of digital global databases of climatic parameters, topography, soil and terrain, and land cover has allowed for revisions and improvements in calculation procedures and to expand assessments of AEZ crop suitability and land productivity potentials to temperate and boreal environments. This effectively enables global coverage for assessments of agricultural potentials.

The AEZ methodologies and procedures have been extended and newly implemented to make use of these digital geographical databases, and to cope with the specific characteristics of growing periods in the seasonal temperate and boreal climates. These methodological adaptations were necessary for the global application and include: (i) enhancement of the thermal regime analysis with quantification of temperature seasonality, (ii) extension of the moisture regime analysis for frozen soils, snow stocks and soil specific water holding capacities, (iii) determination of crop-specific water requirements, deficits, and optimal cropping calendar, and (iv) the application of digital elevation models.

In summary, the following methodological enhancements have been accomplished:

- Selection and definition of additional crop/LUTs relevant to temperate and boreal environments;
- Extension of the crop/LUT definitions to cover irrigated conditions;
- Expansion of crop ecological adaptability inventory;
- Application of soil specific moisture regimes, frozen soil conditions, and snow stocks for the calculation of length of growing periods;
- Application of gridded monthly average (period 1961 to 1990) and historical year-by-year climatic resources databases;
- Application of FAO's Digital Soil Map of the World according to the FAO '74 legend and where available application of soil maps classified according to the revised FAO '90 legend (currently applied for the Former Soviet Union (FSU), Mongolia and China);
- Application of 30-arc second Digital Elevation Model (GTOPO30) for the compilation of a terrain-slope database and integration of the terrain slopes with soil resources database (refining of slope information of soil maps with the slopes derived from the DEM);
- Enhancement of the assessment procedures for year-by-year crop suitability analysis;
- Expansion of the agro-climatic constraints inventory to cover additional crop/LUTs and temperate and boreal environments;
- Assessment of agro-climatic crop suitability by grid-cell (enabling calculations of biomass, constraint-free yields, agro-climatically attainable yields, crop water requirements and deficits);
- Expansion of the land suitability assessment procedures for irrigated crop production.

2. AGRO-ECOLOGICAL ZONES METHODOLOGY

2.1 Introduction

In its simplest form, the AEZ framework contains three basic elements (see Figure 1):

- (i) selected agricultural production systems with defined input and management relationships, and crop-specific environmental requirements and adaptability characteristics. These are termed Land Utilization Types (LUT);
- (ii) geo-referenced climate, soil and terrain data which are combined into a land resources database, and
- (iii) procedures for the calculation of potential yields and for matching crop/LUT environmental requirements with the respective environmental characteristics contained in the land resources database, by land unit and grid-cell.

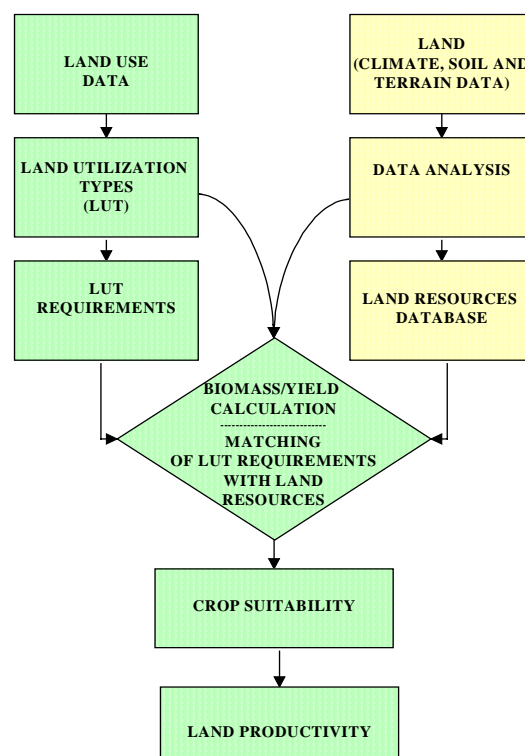


Figure 1 Conceptual framework of Agro-Ecological Zones methodology

Over the past twenty years, the term *agro-ecological zones methodology* has become widely used. However, it has been associated with a wide range of different activities which are often related yet quite different in scope and objectives. FAO and IIASA differentiate the AEZ methodology in the following activities:

First, AEZ provides a standardized framework for the characterization of climate, soil and terrain conditions relevant to agricultural production. In this context, the concepts of Length of Growing Period (LGP) and of latitudinal thermal climates have been applied in mapping activities focussing on zoning at various scales, from sub-national to global level.

Second, AEZ matching procedures are used to identify crop-specific limitations of prevailing climate, soil and terrain resources, under assumed levels of inputs and management conditions. This part of the AEZ methodology provides maximum potential and

agronomically attainable crop yields for basic land resources units (usually grid-cells in the recent digital databases).

Third, AEZ provides the frame for various applications. The previous two sets of activities result in very large databases. The information contained in these data sets form the basis for a number of AEZ applications, such as quantification of land productivity, extents of land with rain-fed or irrigated cultivation potential, estimation of the land's population supporting capacity, and multi-criteria optimization of land resources use and development.

Chapters 2 to 4 present the calculation procedures as used in the Global AEZ (GAEZ) assessment to establish the land resources characterization and the crop yield and suitability databases. Chapter 5 introduces examples of results from a number of basic applications of the AEZ databases.

2.2 Overview

Figure 2 provides a general overview of the flow and integration of information as implemented in the GAEZ assessment. The figure is explained in the following sub-sections. The sub-section numbering corresponds with the numbers used in the figure.

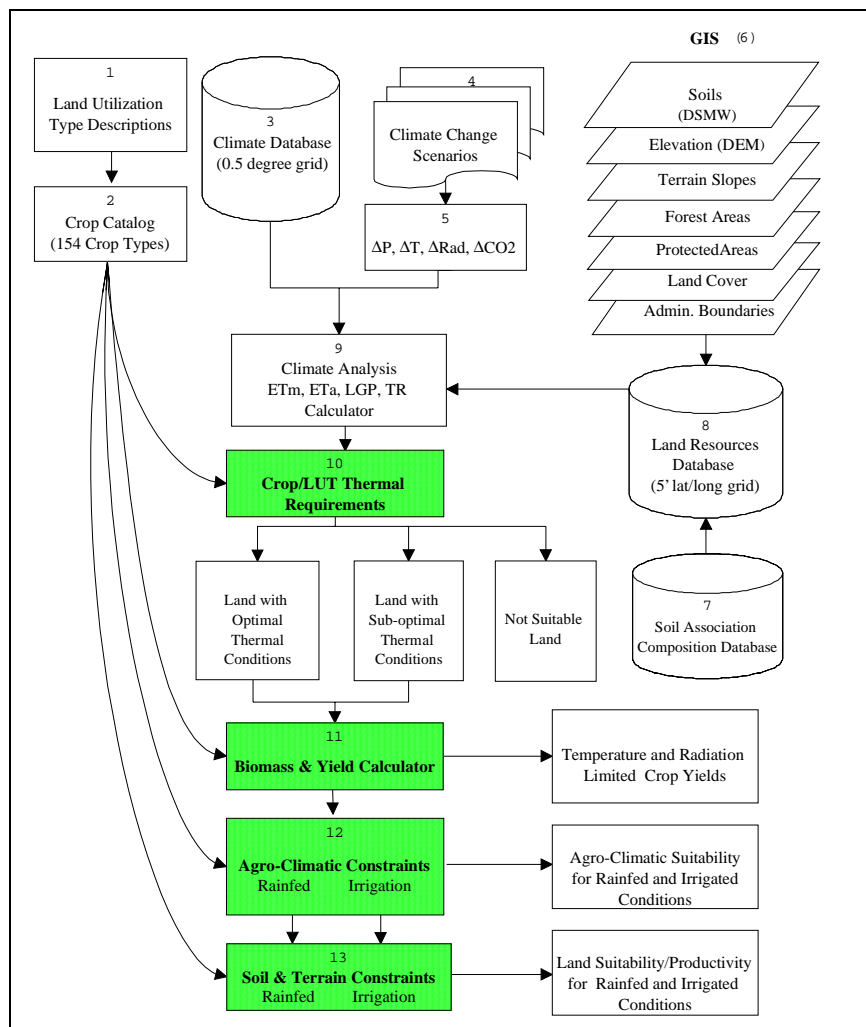


Figure 2 Global Agro-Ecological Zones methodology

(1) **Land utilization types (LUT):** The first step in an AEZ application is the selection and description of land utilization types to be considered in the study. FAO (1984a) defines LUT as follows: ‘A Land Utilization Type consists of a set of technical specifications within a socioeconomic setting. As a minimum requirement, both the nature of the produce and the setting must be specified’.

Attributes specific to particular land utilization types include crop information such as cultivation practices, input requirements, crop calendars, utilization of main produce, crop residues and by-products. For the global study, the AEZ implementation distinguishes 154 crop, fodder and pasture LUTs, each at three generically defined levels of inputs and management, termed high, intermediate and low level of inputs, respectively.

(2) **Crop catalogue:** The crop catalogue database provides a quantified description of LUTs. An example for winter wheat is shown in Table 1.

Table 1 An example of crop parameterization in GAEZ: winter wheat, high level of inputs

Crop characteristics		
Adaptability Group		C3/1
Growth Cycle		110-130 days
Pre-dormancy period		30 days
Post-dormancy period		90 days
Maximum Leaf Area Index		4.5
Crop stages (%)	D1	10
	D2	30
	D3	35
	D4	25
Crop water requirement (Kc-factor)	D1	0.4
	D2	0.4-1.1
	D3	1.1
	D4	1.1-0.4
Moisture-stress related yield reduction (Ky-factor)	D1	0.2
	D2	0.6
	D3	0.75
	D4	0.50
Crop requirements		
Thermal climates		Boreal, Temperate, Subtropics
Temperature profile		see Chapter 4
Growing period		see Chapter 4
Dormancy		required
Post-dormancy accumulated temperature (optimal)		>1,300
Post-dormancy accumulated temperature (sub-optimal)		>1,200
Sensitivity to soil moisture depletion		Class 3
Soil and terrain conditions		see Chapter 4
Crop conversion factors		
Harvest index		0.45
Cereal equivalent ratio		1.0
Extraction rate		75%
Energy contents (Kcal/1000 g)		3640
Protein contents (g/1000 g)		110
Crop residue-factor		1.0
Crop residue utilization rate		40%
Crop by-product factor		0.20
Crop by-product utilization rate		90%

Factors included are crop characteristics such as: crop growth cycle lengths, length of individual crop development stages, photosynthetic pathway, crop adaptability group, maximum leaf area index, harvest index, development stage specific crop water requirement coefficients, yield reduction factors relating moisture stress and yield loss according to FAO (1979), food content coefficients (energy, protein), extraction/conversion rates, crop by-product/residue coefficients, and commodity aggregation weights. Also included are parameters describing for both rain-fed and irrigated LUTs, thermal requirements, growing period requirements and soil and terrain requirements, applicable respectively in tropical, subtropical, temperate and boreal environments.

(3) **Climate database:** Climatic data are an essential requirement for agro-ecological assessments. In the past various efforts have been undertaken to develop global climate databases (e.g., see Kineman and Ohrenschall, 1992). In the GAEZ study a data set has been used which was recently published by the Climate Research Unit (CRU) of the University of East Anglia (New *et al.*, 1998). The CRU database covers all the climate parameters required for GAEZ and consists of data sets describing average climate conditions (years 1961 - 90) as well as data for individual years from 1901 to 1996. Data are organized in a global 30-minute latitude/longitude grid (720x360 grid-cells).

At the present stage computations for average climate conditions, and historical year-by-year calculations for the years 1960 to 1996 have been completed in the GAEZ study².

(4) **Climate scenarios:** A number of sensitivity tests and general circulation models (GCM) based climate scenarios were selected for use in GAEZ. Outputs from six GCM experiments were obtained through the IPCC Data Distribution Centre (DDC). They include the following models/scenarios for the periods 2010-2039, 2040-2069, and 2070-2099:

- (i) *The ECHAM4 model.* This model was developed at the German Climate Research Centre of the Max-Planck-Institute for Meteorology in Hamburg, Germany (Oberhuber, 1993; Roeckner *et al.*, 1992; Roeckner *et al.*, 1996). Model results were taken from the greenhouse gasses forcing scenario and from the greenhouse gasses plus sulfate aerosols forcing scenario. For the latter only the 2010-2039 period was available. The scenario results from ECHAM4 are provided at spatial resolution of approximately 2.8 x 2.8 degrees.
- (ii) *The Canadian Global Coupled Model (CGCM1).* This model was developed at the Canadian Centre of Climate Modelling and Analysis. Model results were taken from the greenhouse gasses forcing scenario and from the average of "ensemble" simulations (ensemble simulations are based on identical historical and future changes in greenhouse gasses, however initiated from different points on the control run). The average "ensemble forcing scenario" was taken for the greenhouse gasses plus sulfate aerosols. The scenario results from CGCM1 are provided at spatial resolutions of 3.75 x 3.75 degrees (Boer *et al.*, 1998; Flato *et al.*, 1998).
- (iii) *The HadCM2 model.* This model is based on recent experiments performed at the Hadley Centre for Climate Prediction and Research (Murphy, 1995; Murphy and Mitchell, 1995). Model results were taken from the average of "ensemble" simulations. The average of "ensemble forcing scenarios" were used for respectively

² For average climate conditions results were obtained also with the CLIMATE database of Cramer and Leemans (an update and extension of Leemans and Cramer (1991)). Note also, that these climate data sets are not available from FAO or IIASA, but can be obtained from the respective authors.

greenhouse gasses only and for greenhouse gasses plus sulfate aerosols. The scenario results from HadCM2 are available at a spatial resolution of 3.75 x 2.75 degrees.

For use in GAEZ, outputs of the above six climate model experiments, available for three time periods and with various spatial resolutions, have been interpolated to 0.5 x 0.5 degrees.

(5) **Scenario-derived climatic parameters:** At minimum, four climatic parameters from the GCM results were used to adjust the baseline climate conditions of each grid-cell. The *difference* in monthly mean maximum and minimum temperatures, between a GCM climate change run and the respective GCM control experiment (representing approximately current base climate), were added respectively to the mean monthly maximum and minimum temperatures of the baseline climate surfaces. Multipliers, i.e., the *ratio* between GCM climate change and control experiment, were used to impose changes in precipitation and incident solar radiation, respectively. When available from a GCM, changes in wind speed and relative humidity were considered as well. Each climate scenario is also characterized by level of atmospheric CO₂ concentrations and assumed changes of crop water-use efficiency. These parameters affect both the estimated reference evapotranspiration as well as the crop biomass estimations.

(6) **Land characteristics coverages (GIS):** Soils, physiography, elevation, terrain slopes, protected areas, present land cover, and administrative divisions are kept as individual layers in the geographical information system and can be combined as needed.

Digital soil information for GAEZ was obtained from FAO. The Digital Soil Map of the World (DSMW, version 3.5) provides classification at 5-minutes latitude/longitude grid-cells and global coverage of soils according to the FAO '74 legend (FAO, 1995c)³.

For elevation the GTOPO30 data set was used (EROS Data Center, 1998a). At IIASA rules based on altitude differences of neighboring grid-cells were applied to compile a terrain-slope distribution database (by FAO DSMW 5-minute grid-cell) in terms of seven average slope range classes⁴.

A coverage of protected areas was obtained from the FAO GIS in Rome. The version currently available in the GIS covers legally protected areas in developing countries only.

Distributions of present land cover for each 5-minute latitude/longitude grid-cell of the DSMW were derived from a global 1km land cover data set (EROS Data Center, 1998b).

(7) **Soil association composition database:** The composition of the soil associations in terms of percentage occurrence of soil units, soil phases, textures and terrain-slope classes is stored in the soil association composition database. For the characterization of the soil units in terms of physical and chemical properties, use has been made of (i) the soil unit characteristics database from the FAO DSMW CD-ROM (FAO, 1995c), and (ii) the soil profile database of the World Inventory of Soil Emissions Potential (WISE) (Batjes, 1995). The latter database provides information on physical and chemical soil attributes for soil units of both the FAO '74 and the FAO '90 classifications. (FAO/IIASA/ISRIC, 1997).

³ It should be noted that GAEZ is also ready to operate with updates of the DSMW. For instance, for the countries of the former Soviet Union (FSU), Mongolia and China recently updated soil maps in digital format provide classifications in terms of the FAO '90 revised legend (Stolbovoi, 1998; FAO/IIASA, 1999).

⁴ Due to the size of grid-cells, algorithms calculating slope angles among neighboring 30 arc-sec grid-cells of GTOPO30 give unrealistic slope distributions that overestimate extents of terrain with flat and undulating slopes.

(8) **Land resources database (GIS):** The individual GIS layers with their attribute data and distributions at 5-minutes latitude/longitude constitute the land resources database. The key components of this database include the FAO DSMW and linked soil association composition table, the 5-minute latitude/longitude slope distribution database derived from GTOPO30, and a database derived from the USGS 1 km seasonal land cover data set providing distributions in terms of eleven aggregate land-cover classes for each 5-minute grid-cell of the DSMW.

The DSMW has been made the reference for constructing a land surface mask, i.e., a binary layer that distinguishes grid-cells as land or sea, respectively. Also, each 5-minute grid-cell is uniquely assigned to an administrative unit, a country or disputed area.

(9) **Climate data analysis (ET_0 , ET_a , LGP and TR calculation):** From the attributes in the climate database, monthly totals of reference evapotranspiration (ET_0) are calculated for each grid-cell according to the Penman-Monteith equation (FAO, 1992b). A water-balance model, comparing moisture supply to crops from precipitation and storage in soils with potential evapotranspiration, provides estimations of actual evapotranspiration (ET_a), and length of growing period (LGP). The LGP calculations also indicate the number and type of growing periods per year, their starting and ending dates, and moisture excess and deficits during the growing periods. Further explanations of the moisture balance calculations are provided in Section 3.1.4; calculation of ET_0 is described in Appendix V.

Table 2 Climate parameters for Bangkok, Harbin, Manaus, Marseille, Nairobi and Vienna

Parameter	Bangkok	Harbin	Manaus	Marseille	Nairobi	Vienna
Mean temperature	28.4	4.1	27.3	13.4	18.3	9.8
Thermal climate ⁵	1	6	1	3	1	5
Temperature profile	Table 3.3	Table 3.3	Table 3.3	Table 3.3	Table 3.3	Table 3.3
Precipitation	1,188	524	2,273	749	976	622
ET_0	1,641	968	1,481	1,215	1,629	860
ET_a	1,042	510	1,354	745	932	602
LGP $t=0$	365	305	365	365	365	318
LGP $t=5$	365	291	365	365	365	243
LGP $t=10$	365	274	365	226	365	185
TSUM $t=0$	10,350	3,211	9,950	4,906	6,688	3,625
TSUM $t=5$	10,350	3,143	9,950	4,906	6,688	3,454
TSUM $t=10$	10,350	2,885	9,950	3,922	6,688	3,020
LGP (total)	239	129	365	269	208	243
Number of LGPs	1	2	1	1	2	1
Beginning LGP 1	124	day 175	n.a.	day 262	day 84	day 74
End LGP 1	362	day 291	n.a.	day 165	day 218	day 314
Beginning LGP 2	n.a.	day100	n.a.	n.a.	day 306	n.a.
End LGP 2	n.a.	day 111	n.a.	n.a.	day 13	n.a.
Annual P/ ET_0	0.72	0.54	1.53	0.62	0.60	0.72

Thermal regimes (TR) are quantified for each grid-cell in terms of four kinds of attributes (see also examples in Table 2), namely: thermal climates, temperature profiles, temperature growing periods (LGP_t), and accumulated temperature (TSUM) calculated for various base temperatures both over an entire year as well as over growing period days. Thermal regimes are further discussed in Section 3.1.3.

⁵ 1: Tropics, 3: Sub-tropics winter rainfall, 5: Temperate sub-continental, 6: Temperate continental

(10) **Crop/LUT thermal requirements:** Temperature profile requirements, temperature growing period requirements, and temperature sum requirements of LUTs are matched with actual temperature regimes in grid-cells. The temperature profile requirements of crops are formulated on the basis of temperature intervals of 5°C, determined separately for seasons with increasing and decreasing temperature trends. These periods are matched with the temperature profiles calculated from temperature data. When the temperature characteristics in a particular grid-cell match respectively the temperature profile requirement, minimum length of temperature growing period, and accumulated temperature requirements, then the crop LUT is considered for cultivation and biomass/yield calculations are performed. A more detailed discussion of crop/LUT thermal requirements is presented in Chapter 4.

(11) **Biomass and yield calculation:** The calculation of biomass and crop yield used in GAEZ is based on Kassam (1977) and FAO (1979, 1992a). The *constraint-free crop yields* computed in the biomass module (see Appendix VI) reflect yield potentials with regard to temperature and radiation regimes prevailing in the respective grid-cells. Results are geographical distributions of temperature and radiation limited yields of individual crop/LUTs.

(12) **Agro-climatic constraints:** Agro-climatic constraints have their origin primarily due to climate, and cause direct or indirect losses in the yield and quality of produce. Yield losses of a rain-fed crop due to agro-climatic constraints are influenced by the following conditions:

- The variability and degree of water-stress during the growing period;
- The yield-quality reducing factors of pests, diseases and weeds;
- The climatic factors, operating directly or indirectly, that reduce yield and quality of produce mainly through their effects on yield components and yield formation;
- The climatic factors which effect the efficiency of farming operations and costs of production;
- The risk of occurrence of late and early frost.

The agro-climatic constraints in GAEZ are specified by means of adjustment factors linked to the standardized evaluation of the temperature and moisture regimes in each grid-cell, i.e., they are essentially formulated based on length of thermal growing period (LGP_t) and length of moisture growing period (LGP). In addition, the factors depend on crop type and level of inputs/management.

(13) **Soil and terrain constraints:** The agro-edaphic suitability assessment is based on the comparison of edaphic requirements of rain-fed and irrigated crop/LUTs and prevailing soil and terrain conditions. The edaphic assessment also reflects constraints imposed by landform and other features that do not directly form a part of the soil but may have a significant influence on the use that can be made of the soil. Distinction is made between *internal* soil requirements of crop/LUTs, such as soil temperature regime, soil moisture regime, soil fertility, effective soil depth for root development, and other physical and chemical soil properties, and *external* requirements related to soil slope, occurrence of flooding and soil accessibility.

The results of matching the crop/LUT-specific edaphic requirements to the soil and terrain attributes of individual grid-cells, in combination with calculated potential biomass and agro-climatically attainable yields, provides a suitability classification for each rain-fed and irrigated crop/LUT respectively at high, intermediate and low levels of input circumstances.

In order to safeguard production to be achievable on a sustainable basis, two further considerations are applied in the assessment:

- Fallow requirements are imposed to enable maintenance of soil fertility and structure and counteracting soil degradation caused by cultivation. Fallow requirements vary by environmental conditions, crop, and level of inputs/management (FAO/IIASA, 1991). Principles of formulating fallow requirement factors in GAEZ are discussed in Section 4.4.3.
- The terrain-slope suitability classification is concerned not only with workability and accessibility of the land but also with the prevention of intolerable levels of topsoil erosion and fertility loss. Depending on prevailing rainfall aggressivity, level of inputs/management, and crop/LUT, upper limits have been set to slope gradients considered suitable for cultivation.

3. LAND RESOURCES

The AEZ methodology for land productivity assessments follows an environmental approach; it provides a framework for establishing a spatial inventory and database of land resources and crop production potentials. This land resources inventory is used to assess, for specified management conditions and levels of inputs, the suitability of crops/LUTs in relation to both rain-fed and irrigated conditions, and to quantify expected production of cropping activities relevant in the specific agro-ecological context. The characterization of land resources includes components of climate, soils, landform, and present land cover.

Inherent in the methodology is the generation of a climatic inventory to predict agro-climatic yield potentials of crops. The Global AEZ study uses a recent global climatic data set compiled by the Climate Research Unit at the University of East Anglia. The database offers a spatial resolution of 30 minutes latitude/longitude and contains climate averages for the period 1961-90 as well as year-by-year data of the period 1901-1996. These are used to characterize each half-degree grid-cell in terms of applicable thermal climates, temperature profiles, accumulated temperature sums, length of growing periods, moisture deficits, etc.

Adequate agricultural exploitation of the climatic potentials and maintenance of land productivity largely depend on soil fertility and the management of soils on an ecologically sustained basis. Hence, the climatic inventory was superimposed on FAO's Digital Soil Map of the World (DSMW). The DSMW is derived from the FAO/UNESCO Soil Map of the World at scale 1:5 million and presents soil associations in grid-cells of 5-minutes latitude/longitude, forming the basis of soil information in Global AEZ. The composition of soil associations is described in terms of percentage occurrence of soil units, soil phases and textures. Therefore, each 5-minute grid-cell is considered as consisting of several land units.

Terrain slopes were derived from the GTOPO30 database developed at the USGS Eros Data Center, providing digital elevation information in a regular grid of 30 arc-seconds latitude/longitude. At IIASA rules based on altitude differences of neighboring grid-cells were applied to compile a terrain-slope distribution database (for each 5-minute grid-cell of FAO's DSMW) in terms of seven average slope range classes.

The individual GIS layers with attribute data and distributions at 5-minutes latitude/longitude constitute the land resources database. The key components of this database include: the FAO DSMW and linked soil association composition table, the slope distribution database derived from GTOPO30, and an ecosystem database derived from the USGS 30 arc-second seasonal land cover data set providing distributions in terms of twelve aggregate land-cover classes for each 5-minute grid-cell. The DSMW has been made the reference for constructing a land surface mask, i.e., a binary layer that distinguishes grid-cells as land or sea, respectively. Also, each 5-minute grid-cell is uniquely assigned to an administrative unit (a country or region).

3.1 Climate resources

3.1.1 Introduction

Living organisms require heat, light and water in varying amounts. Their distribution, in space and time, is governed by these climatic elements. In the AEZ approach, as in any biogeographic inventory, temperature, water and solar radiation are the key climatic parameters. These parameters condition rates of net photosynthesis allowing plants to accumulate dry matter and to accomplish the successive plant development stages. Data on climatic requirements of crop growth, development and yield formation are the basis for the compilation of the AEZ climatic inventory. Also, crops need to be characterized for their

thermal and moisture adaptability. Prevailing temperatures determine crop performance when moisture conditions are met. Similarly, when temperature requirements are met, the growth of a crop is dependent on how well its growth cycle fits within the period when water is available. The latter has led to the concept of *length of growing period* (LGP). It provides for an environmental characterization particularly relevant to agricultural assessments. The length of growing period is defined as the number of days when water availability and prevailing temperatures permit crop growth. Depending on its length, the growing period may allow for no or for only one crop per year (e.g., in arid or dry semi-arid tropics), or it may allow to grow a sequence of crops within one year (e.g., in humid tropics or subtropics). In the Global AEZ implementation, LGP is used to determine periods within a year available for rain-fed crop production, and to select applicable agro-climatic constraints.

3.1.2 Climate data

The Global AEZ study uses a recent global climate data set, which is here referred to as the ‘CRU’ climate database. It has been compiled by the Climate Research Unit (CRU) of the University of East Anglia (New *et al.*, 1998). This database comprises a suite of nine climatic variables interpolated from observed station data to a 30 minutes latitude/longitude grid. Each data set contains 720x360 grid-cells (however, only grid-cells over land are provided). In addition to the 1961-90 climate averages, historical gridded data was obtained from CRU, comprising year-by-year data of the period 1901-1996 also in the form of 30 minutes latitude/longitude grids. The mean monthly climate attributes include: precipitation, wet-days frequency, mean temperature, diurnal temperature range, sunshine duration, windspeed, and vapour pressure. Table 3 presents the climate parameters held in the CRU database by grid-cell.

Table 3 Attributes in the CRU climate databases

Monthly variables (Normals 1961-1990)	Monthly variables (Historical data 1901-1996)
<ul style="list-style-type: none"> • Precipitation • Wet days frequency • Mean temperature • Diurnal temperature range • Vapour pressure • Cloud cover • Sunshine (n/N) • Ground-frost frequency • Windspeed 	<ul style="list-style-type: none"> • Precipitation • Wet days frequency • Mean temperature • Diurnal temperature range • Vapour pressure

The year-by-year historical databases, along with the 1961-90 average climate database, have been used to quantify growing period variability and to estimate for each grid-cell by crop/LUT the variability of agro-climatically attainable crop yields. Average annual rainfall and estimated reference evapotranspiration, calculated according to Penman-Monteith have been compared with average data from climate stations of the FAOCLIM database (FAO, 1995b). Their correlation is shown in Figure 3 below⁶.

⁶ There are several important reasons why station data and values obtained from grid-cells can (and should) be different: (i) the observation period of stations and the 1961-90 climate normals of the CRU grid can be quite different both in time and number of years; (ii) the grid values represent average conditions for a 0.5 degree latitude/longitude cell-size; in complex terrain or for areas with strong moisture gradients this heterogeneity can lead to large discrepancies.

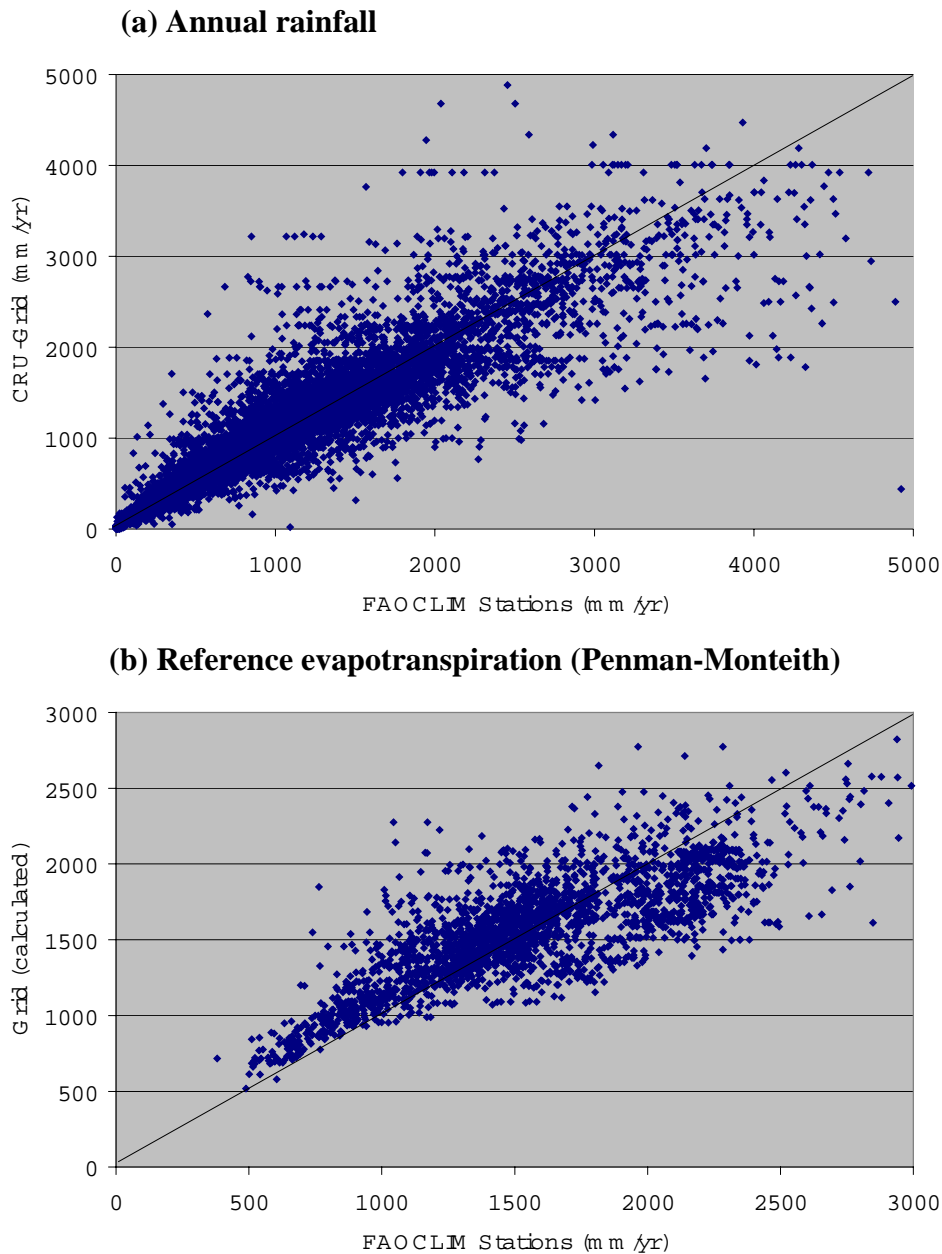


Figure 3 Scattergram of (a) annual rainfall and (b) reference evapotranspiration (Penman-Monteith), between grid-cell data from the CRU 1961-90 climate normals database and average station data of the FAOCLIM database.

Maps of annual rainfall and reference evapotranspiration totals are reproduced in Appendix XV, i.e., Plate 1 – Average annual precipitation, and Plate 2 – Average annual reference evapotranspiration (according to Penman-Monteith).

3.1.3 Thermal regimes

Photosynthesis produces the sources of assimilates which plants use for growth and development. Temperature and radiation influence the rate of photosynthesis. However, plants also have an obligatory development in time, which must be met if the photosynthetic assimilates are to be converted into economically useful yields of satisfactory quantity and quality. Temperature (and day-length in case of photosensitive crops) influences the developmental sequence of crop growth in relation to crop phenology. Therefore, the temperature regime and photo-periodicity govern the selection of the crops that can be

cultivated. In some cases, temperature may determine whether a particular development process will be initiated or not (e.g., chilling requirements for initiation of flower buds). Low temperatures can also delay flowering and fruit setting. For photosensitive cultivars, day-length plays an important role in determining the time of flowering. For instance, many soybean varieties will not flower under equatorial conditions. Deepwater rice flowers after the day-length has shortened to a certain amount of day-light hours, which coincides in Southeast Asia with the end of the rainy season.

The evolutionary changes that have occurred in the biochemical and physical characteristics of photosynthesis have resulted in a large variation between crops in both their optimum temperature requirements and the responses of photosynthesis to changes in temperature and radiation. These responses depend on the nature of the photosynthetic pathway. In general, the C_3 pathway of assimilation is adapted to operate at optimum rates under lower temperature conditions than the C_4 assimilation pathway. However, breeding and selection (both natural and under human influence) have changed temperature responses of photosynthesis in some C_3 and C_4 species. It is therefore possible to make a division of the major food crops according to their assimilation pathway and corresponding temperature requirements. Four groups have been recognized in AEZ:

- Group I* C_3 species adapted to lower temperatures (e.g., wheat, potatoes);
- Group II* C_3 species adapted to higher temperatures (e.g., soybean, rice, cassava);
- Group III* C_4 species adapted to high temperatures (e.g., millet, sorghum, maize, sugarcane);
- Group IV* C_4 species adapted to lower temperatures (e.g., sorghum, maize).

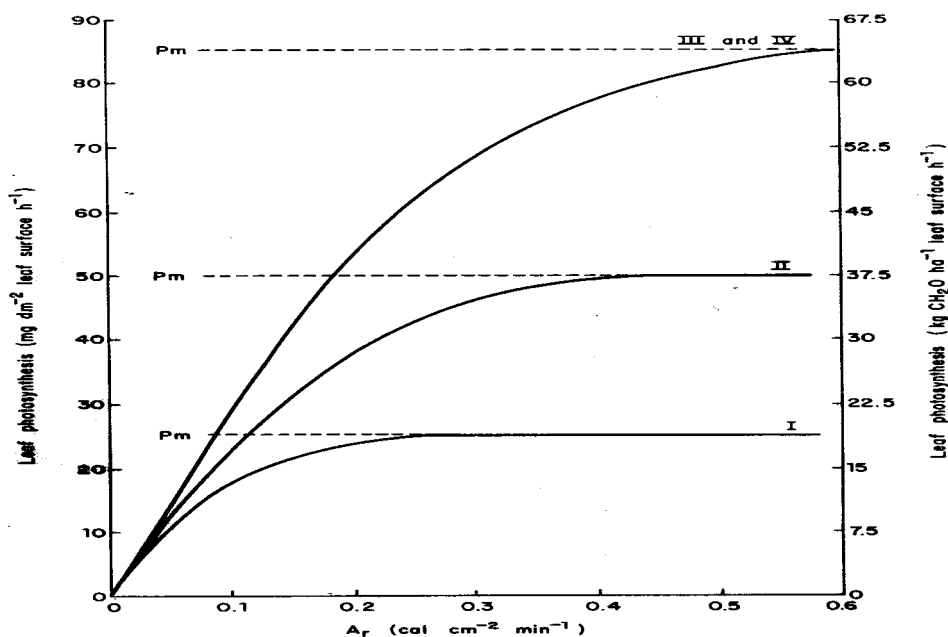


Figure 4 Relationship between leaf photosynthesis rate⁷ at optimum temperature and photosynthetically active radiation (A_r) for crop groups I, II, III and IV (FAO, 1978-81a)

Figure 4 shows for each crop group examples of the relationship between the rate of photosynthesis at optimum temperature and photosynthetically active radiation. Figure 5

⁷ The leaf photosynthesis values presented in Figure 4 and 5 reflect present levels of atmospheric carbon dioxide concentrations.

illustrates for each group of crops the typical (inverted) u-shaped effect of temperature on the leaf photosynthesis.

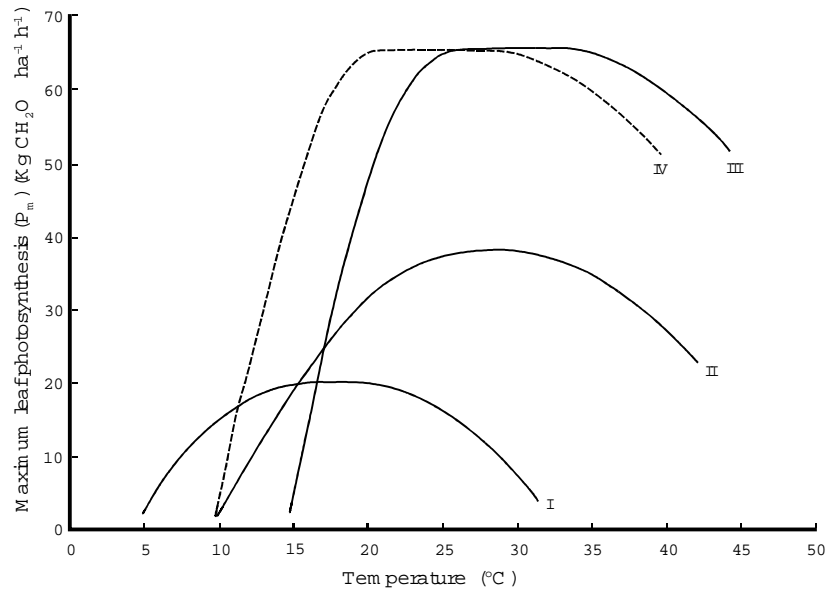


Figure 5 Examples of relationships between maximum leaf photosynthesis rate (P_m) and temperature for crop groups I, II, III and IV (FAO, 1978-81a)

To cater for differences in thermal requirements of crops, an adequate characterization of the temperature regimes is required, applicable for a wide range of locations. With the improved spatial availability of climate attributes and the extension of Global AEZ to temperate and boreal seasonal climates, the characterization of the temperature regimes in the present approach comprises four parts, namely:

- Thermal climates, representing major latitudinal climatic zones;
- Temperature profiles, providing quantification of temperature seasonality;
- Temperature growing periods (LGP_T), representing the periods during which average daily temperatures exceed specified minimum levels; and
- Accumulated temperature, calculated for various base temperatures.

Thermal Climates

The thermal climates are obtained through classifying of monthly temperatures corrected to sea level (with an assumed lapse rate: $0.55^\circ\text{C}/100\text{m}$). For the classification of latitudinal thermal climates, the AEZ major climatic divisions of tropics, subtropics with summer rainfall, subtropics with winter rainfall, and temperate (FAO, 1978-81a), have been expanded with boreal and polar/arctic divisions. The temperate and boreal belts have been further subdivided according to continentality into three classes, namely: oceanic, sub-continental and continental. Table 4 presents the thermal climate classification used in the GAEZ study. The geographic distribution of the thermal climates is presented in Plate 3 (see Appendix XV).

Table 4 Thermal climates

Thermal climate classification	
<p><i>Tropics</i> All months with monthly mean temperatures, corrected to sea level, above 18°C</p>	
<p><i>Subtropics</i> One or more months with monthly mean temperatures, corrected to sea level, below 18°C but above 5°C</p>	<p><i>Subtropics Summer Rainfall</i> Northern hemisphere: rainfall in April-September \geq rainfall in October-March Southern hemisphere: rainfall in October-March \geq rainfall in April-September</p>
	<p><i>Subtropics Winter Rainfall</i> Northern hemisphere: rainfall in October-March \geq rainfall in April-September Southern hemisphere: rainfall in April-September \geq rainfall in October-March</p>
<p><i>Temperate</i> At least one month with monthly mean temperatures, corrected to sea level, below 5°C and four or more months above 10°C</p>	<p><i>Oceanic Temperate</i> Seasonality less than 20°C*</p>
	<p><i>Sub-continental Temperate</i> Seasonality 20-35°C*</p>
	<p><i>Continental Temperate</i> Seasonality more than 35°C*</p>
<p><i>Boreal</i> At least one month with monthly mean temperatures, corrected to sea level, below 5°C and more than one but less than four months above 10°C</p>	<p><i>Oceanic Boreal</i> Seasonality less than 20°C*</p>
	<p><i>Sub-continental Boreal</i> Seasonality 20-35°C*</p>
	<p><i>Continental Boreal</i> Seasonality more than 35°C*</p>
<p><i>Polar/Arctic</i> All months with monthly mean temperatures, corrected to sea level, below 10°C</p>	

* Seasonality refers to the difference in mean temperature of the warmest and coldest month, respectively.

Temperature profiles

The quantification of temperature seasonality looks at year-round temperature regimes. They are expressed in number of days falling into pre-defined temperature intervals. These intervals comprise of five-degree centigrade steps, subdivided respectively in periods with increasing and decreasing temperatures. ‘A’ classes are used for increasing temperatures and ‘B’ classes for decreasing temperatures. A complete account of time periods of individual temperature intervals provides a year-round *temperature profile*. These profiles have been calculated for each grid-cell; examples are shown in Table 5.

Table 5 Examples of average temperature profiles for Bangkok, Harbin, Manaus, Marseille, Nairobi and Vienna

Temperature intervals		Temperature Periods (days)					
		Bangkok	Harbin	Manaus	Marseille	Nairobi	Vienna
A9	< -5°C	0	56	0	0	0	0
A8	-5-0°C	0	14	0	0	0	23
A7	0-5°C	0	13	0	0	0	36
A6	5-10°C	0	17	0	79	0	32
A5	10-15°C	0	22	0	43	0	33
A4	15-20°C	0	27	0	40	227	74
A3	20-25°C	0	38	0	33	9	0
A2	25-30°C	95	0	258	0	0	0
A1	> 30°C	21	0	0	0	0	0
B1	> 30°C	25	0	0	0	0	0
B2	30-25°C	224	0	107	0	0	0
B3	25-20°C	0	32	0	43	8	0
B4	20-15°C	0	20	0	38	121	49
B5	15-10°C	0	19	0	29	0	29
B6	10-5°C	0	17	0	60	0	26
B7	5-0°C	0	14	0	0	0	39
B8	0- -5°C	0	13	0	0	0	24
B9	< -5°C	0	63	0	0	0	0

Temperature growing periods and temperature sums

In addition to thermal climates and temperature profiles, temperature growing periods (LGP) have been inventoried. For instance $LGP_{t=5}$ of 5°C, i.e., the number of days when mean daily temperature exceeds 5°C, represents the period with temperatures suitable for crop growth. Similarly $LGP_{t=10}$ of 10°C approximates the frost-free period (see Plates 4 and 5 in Appendix XV). Lengths, beginning dates and ends of such periods are calculated for each grid-cell and are stored in the attribute database. Also, for various base temperatures, accumulated temperatures have been calculated for each grid-cell. For instance, the accumulated temperature on days with mean daily temperature above 0°C is shown on Plate 6 in Appendix XV.

3.1.4 Moisture regimes

A general characterization of moisture conditions is achieved through the concept of *length of growing period* (LGP), i.e. the period during the year when both moisture availability and temperature are conducive to crop growth. Thus, in a formal sense, LGP refers to the number of days within $LGP_{t=5}$ when moisture conditions are considered adequate.

Under rain-fed conditions within $LGP_{t=5}$, the begin of the LGP is linked to the start of the rainy season. Farmers' cropping strategies are undoubtedly influenced by the variability they have experienced in the onset of the rainy season. In general, they will plant or dry-seed their crop when certain amounts of rainfall have accumulated and sufficiently moistened the topsoil. The start of the growing period is therefore dependent on the amount and frequency distribution of early rains. The reliability of precipitation of these early rains increases considerably once the monthly precipitation equals or exceeds half the potential

evapotranspiration (FAO, 1978-81a). Furthermore, the amount of moisture required to sustain growth of germinating crops is well below evapotranspiration demand of crops at maximum canopy cover. For establishing crops, 0.4 - 0.5 times the level of reference evapotranspiration (i.e., potential evapotranspiration of a reference crop; see Appendix V) is considered sufficient to meet water requirements of dryland crops (FAO 1978-81a; 1979; 1992a).

The growing period for most crops continues beyond the rainy season and, to a greater or lesser extent, crops mature on moisture stored in the soil profile. However, the amount of soil moisture stored in the soil profile, and available to a crop, varies, e.g., with depth of the soil profile, the soil physical characteristics, and the rooting pattern of the crop. Depletion of soil moisture reserves causes the actual evapotranspiration to fall short of the potential rate. Soil moisture storage capacity of soils (*S_{max}*) depends on soil physical and chemical characteristics, but above all on effective soil depth or volume. For the soil units of the Legend of the Soil Map of the World (FAO, 1974), FAO has developed procedures for the estimation of *S_{max}* (FAO, 1995c). The results are summarized in Table 6. The *S_{max}* classes are estimated for individual FAO soil units and are presented in Appendix XIII. For each mapping unit (and each grid-cell) the composition in terms of soil units and the occurrence of soil depth/volume limiting soil phases is known from the DSMW. The relevant *S_{max}* values for individual soil units in a grid-cell were used to set limits to available soil moisture, enabling calculation of possible extension of the growing period beyond the end of the rainy season by soil unit, soil texture class, and soil phase.

Table 6 Soil moisture storage capacity (*S_{max}*) classes derived for FAO soil units and for soil depth/volume limiting soil phases

CLASS	(mm)	Soils with Lithic Phase (mm)	Soils with Petroferric and Duripan Phases (Revised Legend '90) or Petrocalcic, Petrogypsic, Petroferric and Duripan Phases (Legend '74)	Soils with Skeletic and Rudic Phases (Revised Legend '90) or Petric and Stony Phases (Legend '74)
1	150 mm	50 mm	115/50 mm	75 mm
2	125 mm	40 mm	90/40 mm	65 mm
3	100 mm	35 mm	75/35 mm	50 mm
4	75 mm	25 mm	55/25 mm	40 mm
5	50 mm	15 mm	35/15 mm	25 mm
6	15 mm	n.a.	n.a.	n.a.

In addition to taking into account soil specific *S_{max}* values, a number of further modifications in the growing period analysis were introduced. The new elements in the water-balance calculations mainly relate to three types of enhancements:

- (i) temperature/moisture interactions which are of special relevance in temperate and boreal thermal climates;
- (ii) standardization of the water-balance calculations by prior conversion of monthly climate variables to pseudo-daily data (using quadratic spline functions), and
- (iii) enabling ET_0 and water-balance calculations for each 0.5 degree grid-cell.

More specifically the main changes are the following:

- A For the calculation of reference evapotranspiration, the modified Penman equation used in earlier assessments has been replaced by the *Penman-Monteith* equation (FAO, 1992b).

B Monthly climate parameters are converted to daily data by means of spline interpolations, ensuring consistency of daily levels with monthly means or totals. This results for each-grid cell in pseudo-daily values⁸ for all parameters relevant in the calculation of reference evapotranspiration and water-balance.

From these series a daily *water-balance*, W , and *actual evapotranspiration*, ETa , is calculated according to FAO (1979), as follows:

$$W_{j+1} = \min(W_j + P_j - ETa_j, Sa) \quad (1)$$

$$ETa_j = \begin{cases} ETo_j & \text{if } (W_j + P_j) \cdot d \geq Sa \cdot d \cdot (1 - p) \\ \rho ETo_j & \text{else} \end{cases} \quad (2)$$

where,

$$\rho = \frac{ETa_j}{ETo_j} = \frac{W_j + P_j}{Sa \cdot (1 - p)} \quad (3)$$

- j number of day in year
- Sa available soil moisture holding capacity (mm/m)
- d rooting depth (m)
- p soil water depletion fraction below which $ETa < ETo$
- ρ actual evapotranspiration proportionality factor.

Sa and d are defined by the respective values of the soil units in individual grid-cells. The beginning of a growing period is reached when three basic conditions are met:

(i) average daily temperature is above 5°C, (ii) actual evapotranspiration (ETa) exceeds a specified fraction of the estimated reference evapotranspiration, i.e.,

$$ETa_j \geq \alpha ETo_j, \quad \alpha = 0.4 - 0.5^9 \quad (4)$$

and, (iii) sufficient moisture has been accumulated in the soil profile for establishing crops. However, the start of a growing period may be delayed because of excessive wetness due to snowmelt, especially in flat terrain with poorly drained, medium to fine textured soils, e.g., as found in Western Siberia. This might result in saturated soil conditions with low bearing capacities presenting problems for timely seeding/planting. It also will severely affect the oxygen supply to the roots of the hibernating crops.

Depending on the amount of excess moisture the following assumptions were adopted for the delay of the effective start of a growing period:

⁸ This conversion of monthly (or decade) data to daily values simplifies the calculation of soil moisture balances and the determination of length of growing period and growing period characteristics. Note that these pseudo-daily values should not be applied in instances where actual daily weather data is required. However, it means that the current algorithms are applicable with minor modifications when daily data is available.

⁹ In the current calculations of GAEZ the value of $\alpha = 0.5$ was used.

Table 7 Delay of the growing period start due to excess wetness

Excess moisture from snowmelt (mm)	Excess moisture at start of LGP _{t=5} (mm)		Delay of start of growing period due to excess wetness (days)	
	Very poorly drained soils	Poorly/imperfectly drained soils	Very poorly drained soils	Poorly/imperfectly drained soils
40	0	0	0	0
80	20	0	5	0
120	60	30	15	10
180	120	90	30	20
240	180	150	45	30

Note: Drainage classes are according to the FAO Guidelines for Soil Description (FAO, 1990).

A growing period ends when soil moisture supply becomes insufficient or temperature becomes limiting, i.e., on the day when first

$$ETa_j < \beta ETo_j, \quad \beta = 0.4 - 0.5 \quad (5)$$

or when average daily temperature falls below 5°C. In this way all the growing periods within a year are fully determined with starting and ending dates, length in number of days, and reference *ETa* values. Where applicable, the procedure also records the dates and length of a dormancy period (see below) and of any humid period during a growing period, defined as days when rainfall exceeds reference evapotranspiration, i.e., with $P > ETo$.

- C** The water-balance calculation detects and handles specific conditions during cold-breaks or dormancy:
- frozen topsoil: $T_{mean} < 0^\circ C$, then ($ETa = 0$),
 - LAI development expressed as transpiration gradients, after start of growing period or restart after dormancy period.
- D** The calculation procedures include accumulation of snow stocks and the time periods required to melt snow stocks. Two temperature thresholds control the calculations. When maximum daily temperature falls below a defined limit, then any precipitation occurring is assumed to be in the form of snow and is accumulated as snow stock. During such periods it is also assumed that no evaporation takes place. When average daily temperature exceeds the freezing point, melting of snow stocks is modeled by a linear relationship in proportion to maximum daily temperature exceeding a defined threshold.
- E** Discontinuous growing periods with a dormancy period have been separated from those with a cold-break on the basis of temperature limits (T_h) for survival of hibernating crops. In defining respective limits, the impact of the depth of snow cover (S_d) on T_h has been accounted for as follows, defining a threshold in the range between -8 and -22°C:

$$T_h = \begin{cases} -8 - 0.11 \cdot S_d & S_d \leq 127 \text{ cm} \\ -22 & S_d > 127 \text{ cm} \end{cases} \quad (6)$$

An upper limit to the length of the dormancy period can be set. When the duration of the dormancy period exceeds this maximum, the dormancy period is treated as being a cold-break. In the present calculations, the maximum duration of the dormancy period has been set, as a model variable, at 200 days.

F The procedures allow calculation of growing periods for individual years by using in the water balance time-series of monthly rainfall. This provides a quantification of year to year variability of the moisture regime. Figure 6 presents for Gan Zhou, in Jiangxi province in China, the results of LGP analysis with averaged monthly rainfall data of 1961-80 (shown as AV) as compared with monthly data of individual years. The figure highlights the importance of assessing year-by-year conditions rather than using results derived from average climate data. For instance, while the calculations based on averaged climate conditions result in a year round LGP, the individual year results fall in between 260 and 365 days, with an average of 326 days.

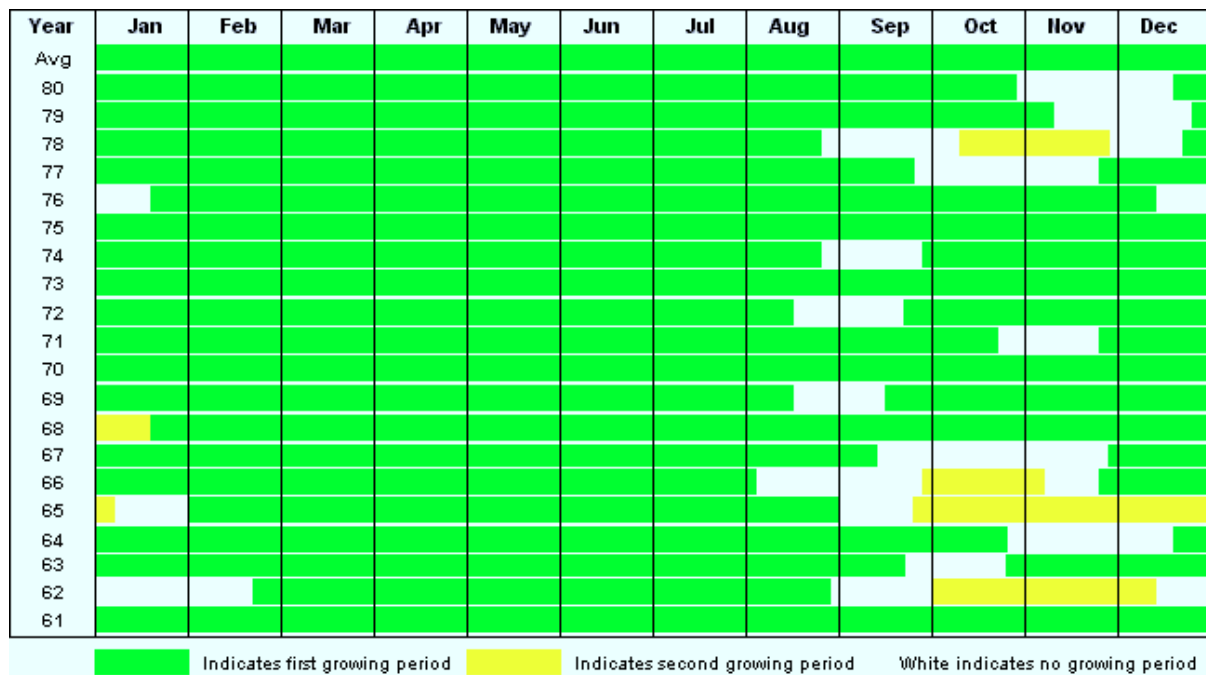


Figure 6 Comparison of LGP calculations for average and year-by-year rainfall, Gan Zhou, China

Plate 7 shows a map of average total length of growing periods (1961-1990). For presentation, the results for each grid cell were grouped in 30-day interval classes. Plate 8 shows a map with dominantly mono-modal and bi-modal growing period patterns, respectively.

3.2 Soil and terrain resources

3.2.1 Soil information

The source of soil information used in Global AEZ is primarily the digital version of the FAO/Unesco Soil Map of the World (FAO, 1995c). It provides classification of soils according to the FAO/Unesco '74 Legend (FAO/Unesco, 1974).

For an increasing number of countries in Africa, South America and Asia the original Soil Map of the World has been or is being updated according to the FAO '90 revised Legend (FAO/Unesco/ISRIC, 1990). The available information concerns the updated soil maps for the former Soviet Union (FSU), Mongolia and China, referred to as Soil and Terrain Database for North and Central Eurasia (FAO/IIASA, 1999), which were finalized in the context of the Land Use Change Project (LUC) of IIASA in close collaboration with FAO. The map covering the territory of the FSU (i.e., Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldavia, Russian Federation,

Tajikistan, Turkmenistan, Ukraine) and Mongolia were compiled at 1:5M scale by Dokuchaev Soil Institute in Moscow (Stolbovoi, 1998). The map covering China at 1:4M scale was compiled by the Institute of Soil Science, Academia Sinica, in Nanjing (FAO/CAS, 1995). Both sets of digital soils information (FAO, 1995c; and FAO/IIASA, 1999) were used for the development of AEZ applications.

The digital soil information constitutes part of the land resources database and is kept together with other geographic information (i.e., elevation, terrain slopes, distance to coast, protected areas, land cover, and administrative divisions). Additional information, specifying the composition of the soil associations in terms of percentage occurrence of soil units, textures, terrain-slope classes and soil phases, is kept in a soil association composition database. The soil units in the FAO legends are defined in terms of measurable and observable properties of the soil itself. Many of the properties are directly relevant to agricultural production potential.

Quantification of soil unit characteristics in terms of physical and chemical properties was obtained from: (i) the DSMW CD-ROM for the soil units of FAO/Unesco 1974 Legend (FAO, 1995c), and (ii) the World Inventory of Soil Emissions Potential (WISE) database (Batjes, 1995). This latter WISE database contains a wide range of soil attributes for over 4000 soil profiles. The International Soil Reference and Information Centre (ISRIC), with assistance of the Land and Water Development Division of FAO, and the LUC project of IIASA have developed procedures for the extraction of relevant soil attributes by soil unit from this WISE soil profile database (Batjes *et al.*, 1997). The individual profiles were classified by ISRIC for both the FAO '74 legend and the FAO '90 revised legend. This facilitates the linkage with the FAO/Unesco Digital Soil Map of the World and the digital soil maps of the FSU, Mongolia and China.

3.2.2 Terrain slopes

Two sources of geo-referenced terrain slopes were available for use in the Global AEZ assessment: (i) terrain slopes indicated in the mapping unit expansion tables of the respective soil maps, and (ii) terrain slopes derived from GTOPO30 data (EROS Data Center, 1998a). The latter terrain-slope database was established at IIASA using a rule-based algorithm to calculate slope distributions in terms of seven slope classes per 5-minute grid-cell of the DSMW soil data based on neighborhood relationships among grid-cells in the 30 arc-second GTOPO30 database (see Appendix II).

Terrain slopes indicated in the DSWM distinguish three broad slope classes as follows:

- Class a: *level to undulating*, dominant slopes ranging between 0 and 8 percent.
- Class b: *rolling to hilly*, dominant slopes ranging between 8 and 30 percent.
- Class c: *steeply dissected to mountainous*, dominant slopes over 30 percent.

The terrain slopes of the DSMW apply to the dominant soil unit of a soil association mapping unit. Where two slopes are indicated for a mapping unit (i.e., a/b or b/c), they apply each to 50 percent of the extent of the dominant soil unit. For all associated and included soils default slope classes are assigned to the individual soil units of FAO '74 according to FAO (1978-81a):

Default slope class	Soil Units in FAO'74
a	Fluvisols, Gleysols, Histosols, Planosols, Solonchaks, Solonetz and Vertisols
a/b	Podzols, Yermosols, Xerosols, Kastanozems, Chernozems, Phaeozems, Greyzems, Luvisols, Podzoluvisols, Ferralsols and Arenosols
b	Regosols, Rendzinas, Cambisols, Acrisols, and Nitosols
b/c	Andosols, Rankers and Lithosols

The above procedure was also adapted for application to the FAO '90 revised legend:

Default slope class	Soil Units in FAO'90
a	Fluvisols, Gleysols, Histosols, Planosols, Solonchaks, Solonetz and Vertisols
a/b	Arenosols, Anthrosols, Chernozems, Ferralsols, Greyzems, Gypsisols, Kastanozems, Luvisols, Lixisols, Podzoluvisols, Phaeozems, Plinthosols, and Podzols
b	Acrisols, Alisols, Calcisols, Cambisols, Nitisols and Regosols
b/c	Andosols, and Lepthosols

The slope classes of the DSMW are very broad and do not reflect the information contained in recent digital data sets. Hence, the above broad slope classes have been refined on the basis of knowledge about soil unit-slope relationships and information derived from GTOPO30. Slopes derived from the 30 arc-second DEM were allocated to soil units occurring within individual soil associations. This involved five steps:

- (i) Determination of slope classes for each 30 arc-second grid-cell of GTOPO30. Results are grouped in the following seven classes: 0-2%, 2-5%, 5-8%, 8-16%, 16-30%, 30-45% and > 45%;
- (ii) Aggregation of the results respectively to 5-minute latitude/longitude DSMW grid-cells, and to individual soil association map units resulting in a slope class distribution for each grid-cell;
- (iii) Defining 'priority' classes of soil unit/slope relationships;
- (iv) Establishing for each soil association consistent rankings of slopes/soil units;
- (v) Allocation of individual soil units within a particular soil association map unit to 5-minute grid-cells of DSMW, according to calculated slope distributions.

Details of the above steps are given in the Appendix II. Plate 9 in Appendix XV presents a map of median terrain slopes derived from GTOPO30.

3.3 Soil and terrain constraints

Additional to the crop-specific suitability assessments (see Chapter 4), the land resources inventory allows characterization of various regions according to the prevailing soil and terrain constraints. A constraint classification has been formulated and has been applied to each grid-cell of the land resources inventory. The constraints considered include:

- Terrain-slope constraints
- Soil depth constraints
- Soil fertility constraints
- Soil drainage constraints
- Soil texture constraints
- Soil chemical constraints

- Presence of miscellaneous land units

The results by grid-cell have been aggregated to countries and regions. They are presented in terms of six broad LGP classes¹⁰ (0 days, 1-59 days, 60-119 days, 120-179 days, 180-269 days, and ≥ 270 days). Details of the constraint classification are listed in Appendix III. Results are presented in Section 5.3, *Climate, Soil and Terrain Constraints to Rain-fed Crop Production*. The geographical distribution of constraints is shown in Pates 41 - 47 in Appendix XV.

¹⁰ In tropical and subtropical lowland zones, where $LGP_{t=5}=365$ days, these broad LGP classes are referred to as respectively: hyper-arid areas (LGP 0 days); arid areas (LGP 1-59 days); dry semi-arid areas (LGP 60-119 days); moist semi-arid areas (LGP 120-179 days); sub-humid areas (180-269 days), and humid areas (LGP ≥ 270 days)

4. CROP/LUT PRODUCTIVITY

4.1 Introduction

This chapter presents the methodology and procedures for the assessment of land productivity potentials for respectively rain-fed and irrigated conditions. For determining irrigated land productivity potentials, it has been assumed that (i) water resources of good quality are available, and (ii) irrigation infrastructure is in place. In other words, the procedures identify areas where climate, soils and terrain permit irrigated crop cultivation, but do not assess availability of sufficient water supply. Note, however, that GAEZ could readily be linked to watershed data to define limits to water availability.

For the assessment of rain-fed land productivity, a water-balance model is used to quantify the beginning and duration of the period when sufficient water is available to sustain crop growth. Soil moisture conditions together with other climate characteristics (radiation and temperature) are used in a simplified and robust crop growth model to calculate potential biomass production and yield. For the assessment of irrigated land productivity the duration of the period with temperatures conducive for crop growth is used for matching the crop cycle length and for the calculation of biomass production and yield. The calculated potential yields are subsequently combined in a semi-quantitative manner with a number of reduction factors directly or indirectly related to climate (e.g., pest and diseases), and with soil and terrain conditions. The reduction factors, which are successively applied to the potential yields, vary with crop type, the environment (in terms of climate, soil and terrain conditions) and assumptions on level of inputs/management.

In order to ensure that the results of the suitability assessment relate to production achievable on a sustainable basis, (i) fallow periods have been imposed, and (ii) terrain slopes have been excluded when inadequate for the assumed level of inputs/management or too susceptible to topsoil erosion.

4.2 Land utilization types

A critical step in implementing any AEZ application is the selection and description of land utilization types. The selection of crops for the present Global AEZ study is based on three considerations, namely: (a) to include the most important food crops, (b) to cover a wide range of natural environments, including those in temperate and boreal zones, and (c) to include, for backward compatibility with earlier AEZ work, all crops previously covered.

The GAEZ study distinguishes in total 154 rain-fed crop, fodder and grassland LUTs, each at three generic levels of inputs and management (high, intermediate and low). For the irrigation land potential assessment, crop LUTs are used at two generic levels of inputs and management (high and intermediate). The full list of crops, fodder and grassland types is presented in Table 8

Relevant crop adaptability and crop requirement data are stored in a crop catalog database. These data sets include for each crop/LUT (and by input level where applicable) the following information:

- (i) crop characteristics: crop growth cycle lengths; relative lengths of crop development stages; photosynthetic pathway; crop adaptability group (defining maximum rates of photosynthesis); development stage specific coefficients relating crop water requirements to reference evapotranspiration (Kc-factors, see FAO (1992a)); moisture stress related yield reduction coefficients (Ky-factors, see FAO (1992a));

Table 8 Crop types included in the Global AEZ study

CROPS	CROP TYPES	CLIMATE ZONES
<i>Cereals</i>		
	(83)	
Wheat (hibernating)	4	Boreal, Temperate and Subtropics
Wheat (non-hibernating)	12	Boreal, Temperate, Subtropics and Tropics
Rice, japonica (wetland)	4	Tropics, Subtropics and Temperate
Rice, indica (wetland)	4	Tropics and Subtropics
Rice (dryland)	3	Tropics
Maize (grain)	13	Tropics, Subtropics and Temperate
Maize (silage)	6	Subtropics and Temperate
Barley (hibernating)	4	Boreal, Temperate and Subtropics
Barley (non-hibernating)	12	Boreal, Temperate, Subtropics and Tropics
Sorghum	7	Tropics, Subtropics and Temperate
Pearl Millet	2	Tropics
Foxtail Millet (Setaria)	4	Subtropics and Temperate
Rye (hibernating)	4	Temperate and Subtropics
Rye (non-hibernating)	4	Boreal, Temperate and Subtropics
<i>Roots and Tubers</i>		
	(8)	
White Potato	4	Boreal, Temperate, Subtropics and Tropics
Cassava	1	Tropics
Sweet Potato	3	Subtropics and Tropics
<i>Pulses</i>		
	(17)	
Phaseolus Bean	9	Tropics, Subtropics and Temperate
Chickpea	5	Subtropics and Tropics
Cowpea	3	Tropics
<i>Oil Crops</i>		
	(25)	
Soybean	6	Tropics, Subtropics and Temperate
Rape (hibernating)	2	Temperate and Subtropics
Rape (non-hibernating)	6	Temperate, Subtropics and Tropics
Groundnut	3	Tropics, Subtropics and Temperate
Sunflower	6	Temperate, Subtropics and Tropics
Oil palm	1	Tropics and Subtropics
Olive	1	Subtropics and Temperate
<i>Fiber Crops</i>		
	(7)	
Cotton	7	Tropics, Subtropics and Temperate
<i>Sugar Crops</i>		
	(6)	
Sugarcane	1	Tropics and Subtropics
Sugar beet	5	Temperate and Subtropics
<i>Fruit Crops</i>		
	(1)	
Banana/Plantain	1	Tropics and Subtropics
<i>Forage/Fodder</i>		
	(5)	
Forage Legume (Alfalfa)	1	Temperate and Subtropics
Pasture Grasses	4	Boreal, Temperate, Subtropics and Tropics
Pasture Legumes	2	Boreal, Temperate, Subtropics and Tropics
<i>Total</i>	<i>154</i>	

- (ii) parameters describing for both rain-fed and irrigated LUTs, thermal requirements, growing period requirements, and soil and terrain requirements, respectively applicable in tropical, subtropical, temperate and boreal environments.
- (iii) factors converting biomass to useful products and commodity aggregates: harvest index; food content coefficients (energy, protein); extraction/conversion rates; crop by-product/residue coefficients, commodity aggregation weights.

4.3 Climatic suitability analysis

The climatic suitability analysis involves matching of crop/LUT requirements with prevailing climatic conditions. It comprises the following activities:

- (a) compilation of crop adaptability inventory for the selected crops and specification of crop/LUT specific temperature and moisture requirements;
- (b) matching crop temperature requirements with prevailing temperature regime;
- (c) determining optimal cropping calendar and calculation of potential biomass and yield;
- (d) calculating crop/LUT specific water deficit and applying moisture stress related yield reduction factors (rain-fed); calculating irrigation water requirements (irrigated);
- (e) formulating of crop/LUT specific agro-climatic constraints, accounting for expected yield losses due to factors related to climate conditions, such as incidence of pests, diseases and weeds, workability, and frost occurrence; application of relevant reduction factors to estimate average attainable yield in each grid-cell.

The results of the climatic suitability analysis are calculated in three steps. Step 1 produces a grid-cell specific agro-climatic characterization, including calculation of thermal climates, temperature profiles, and temperature and moisture growing period characteristics. Step 2 calculates temperature and radiation limited potential crop yields, quantifies moisture stress related yield reductions, and determines optimal crop calendars. Finally, Step 3 provides the average attainable crop yields. Results have been classified in five basic suitability classes according to attainable yield ranges relative to maximum potential crop yields, as follows:

Suitability class		Percentage of maximum
VS	Very Suitable	80 -100
S	Suitable	60 - 80
MS	Moderately Suitable	40 - 60
mS	Marginally Suitable	20 - 40
NS	Not Suitable	0 - 20

4.3.1 Crop thermal requirements and thermal suitability

Temperature and day-length influence the developmental sequence of crop growth in relation to crop phenology. Crop thermal and day-length requirements for both photosynthesis and phenological development have been taken into account in three regards:

- (i) Crops have been classified for day-length requirements. For example, short-day crops have been restricted to the lower latitude tropical zones while long-day crops have been restricted to the higher latitude boreal and temperate zones.
- (ii) A thermal requirements scheme has been devised for each of the 154 crop/LUTs, such that: (a) it covers sufficiently the requirements for photosynthesis and growth, and considers requirements for phenological development of each crop type, and (b) it is applicable in equatorial tropics, and in seasonal subtropical, temperate and boreal climates. The thermal requirements have been formulated in accordance with the temperature profiles which reflect seasonality characteristics of the individual grid-cells (see Section 3.1.3). In this way, the temperature requirements are expressed in terms of the length of periods (duration in days) of the crop cycle falling into temperature intervals of 5°C, separately for increasing and decreasing temperatures. The latter accord with the ‘A’ and ‘B’ type temperature profile periods as described in Section 3.1.3. An example of thermal crop cycle requirements for winter wheat is shown in Figure 7.

The procedures for matching thermal requirements to crop temperature profiles distinguish three cases: *Optimal match* when photosynthesis and phenological temperature requirements are fully met; *Sub-optimal match* when the requirements are just sufficiently met for growth and development; and *Not suitable* when either temperature requirements for photosynthesis or for phenological development are not met.

(iii) Crop growth cycle heat requirements (accumulated temperature in degree-days) have been compared with the accumulated temperature actually available in a grid-cell during the growth cycle. When heat requirements are not met, the temperature regime is considered *not* suitable and no further evaluation of the particular crop/LUT for such a grid-cell is undertaken.

In the grid-cells where thermal requirements of a particular crop/LUT are met in optimal or sub-optimal terms, biomass and yield calculations are performed. Figure 7 shows a representation of thermal requirements for winter wheat. Appendix IV presents the thermal requirements for all the crops considered in Global AEZ.

CROP		WINTER WHEAT (C3/I)			
CLIMATES		Subtropics, Temperate, Boreal			
PHOTO-SENSITIVITY		Day Neutral/Long Day			
GROWTH CYCLES (days) ¹¹		a + b 30 + 90, 35 +105, 40 +120, 45 +135			
TEMPERATURE PERIODS ¹²		Sub-optimal Conditions Percentage of Growth Cycle		Optimal Conditions Percentage of Growth Cycle	
		1 st req.	2 nd req.	1 st req.	2 nd req.
A9	< -5 °C	0	0	0	0
A8	-5-0 °C	0	0	0	0
A7	0-5 °C	0	0	0	0
A6	5-10 °C	≤ 50 % b	> 16.7 % b	≤ 50 % b	> 16.7 % b
A5	10-15 °C	≤ 100 % b		≤ 100 % b	
A4	15-20 °C				
A3	20-25 °C				
A2	25-30 °C		≤ 33.3 % b		≤ 33.3 % b
A1	> 30 °C	0	0	0	0
B1	> 30 °C	0	0	0	0
B2	30-25 °C	≤ 50 % b		≤ 50 % b	
B3	25-20 °C				
B4	20-15 °C		100% a		100% a
B5	15-10 °C				
B6	10-5 °C				
B7	5-0 °C	0	0	0	0
B8	0--5 °C	0	0	0	0
B9	< -5 °C	0	0	0	0
Accumulated temperature during growth cycle (TS _{gc}) ¹³		TS _{gc} > 1300 (post dormancy)		TS _{gc} > 1500 (post dormancy)	
LGP _{t=5}		< 365		< 365	
Dormancy		Required		Required	
Permafrost tolerance		No permafrost		No permafrost	

Figure 7 Temperature profile and thermal requirements for winter wheat

¹¹ a: pre-dormancy part of growth cycle; b: post-dormancy part of growth cycle.

¹² A9-A1: temperature periods with increasing temperatures, i.e., during winter to summer; B1-B9: temperature periods with decreasing temperatures, i.e., from summer to winter.

¹³ Accumulated temperature during post-dormancy part of growth cycle.

4.3.2 Biomass and yield

The constraint-free crop yields calculated in the AEZ biomass model¹⁴ reflect yield potentials with regard to temperature and radiation regimes prevailing in the respective grid-cells. This basically eco-physiological model (Kassam, 1977) requires the following crop characteristics: (a) length of growth cycle (days from emergence to full maturity); (b) length of yield formation period; (c) leaf area index (LAI) at maximum growth rate; (d) harvest index (Hi); (e) crop adaptability group; and (f) sensitivity of crop growth cycle length to heat provision. The biomass calculation includes also simple procedures to account for different levels of atmospheric CO₂ concentrations (Fischer and van Velthuis, 1996). Appendix VI provides details of the calculation procedures and Appendix VII lists the model parameters.

The results of the biomass and yield calculation depend on timing of crop growth cycle (crop calendar). Maximum biomass and yields are separately calculated for irrigated and rain-fed conditions, as follows:

Irrigation:

For each day within the window of time when crop temperature requirements are met optimally or at least sub-optimally¹⁵, the period resulting in the highest biomass and yield is selected to represent the production and crop calendar of the respective crop/LUT for a particular grid-cell.

Rain-fed:

Within the window with optimal or sub-optimal temperature conditions, and starting within the duration of the moisture growing period, the period resulting in the highest expected (moisture-limited) yield is selected to represent maximum biomass and yield for rain-fed conditions of the respective crop/LUT for a particular grid-cell. Moisture limited yields are calculated by applying crop-stage specific and total growing period yield reduction factors (FAO, 1979; FAO 1992a). The yield reduction factors relate relative yield decrease, expressed as $(1-Y_a/Y_m)$, to relative evapotranspiration deficit $(1-ET_a/ET_m)$. In this formulation, Y_a and Y_m denote water-limited and potential yield, respectively; ET_a and ET_m refer to crop-specific actual and potential evapotranspiration in a grid-cell. The obtained relative yield decrease is then applied to the calculated temperature/radiation limited biomass and yield.

In other words, for each crop type and grid-cell the starting and ending dates of the crop growth cycle are determined optimally to obtain best possible crop yields, separately for rain-fed and irrigated conditions. This procedure also guarantees maximum adaptation in simulations with year-by-year historical weather conditions, or under climate distortions applied in accordance with various climate change scenarios. Hence, the AEZ method simulates a 'smart' farmer. Results of the biomass and yield calculations can be presented in tabular or in map form. For instance, Plate 17 in Appendix XV presents a map of temperature and radiation limited yields for wheat.

¹⁴ The calculated biomass and yields are used to formulate indicative yield ranges for each of the five suitability classes employed at each of the three input circumstances.

¹⁵ Only in cases where conclusive data on crop temperature requirements are available, distinction between optimal and sub-optimal conditions could be made.

4.3.3 Crop moisture requirements and growing period suitability

Crop water requirements are for most crops well established and published widely. Various aspects relevant to crop moisture requirements are included in the crop catalog data files: crop growth cycle length, crop stage specific water requirement coefficients, moisture deficit related yield reduction coefficients.

To cater for differences in soil types, the crop cycle matching and biomass calculations were performed for each of the six soil moisture storage capacity (S_{max}) classes (see Table 6). Moisture-limited yields of annual rain-fed crops have been calculated by applying crop stage specific and total growing period yield reduction factors in accordance with procedures developed by FAO (1992a) and as described in the calculation of biomass and yield. This allows the relevant result to be applied for each of the soil types occurring in a particular soil mapping unit of the FAO DSMW.

Perennial crops (i.e., cassava, sugar cane, banana, oil palm, olive, alfalfa, grass/legume mixtures, and grasses) are matched to moisture conditions of the calculated growing periods. This involves the following steps: (i) how well the crop growth cycle fits within the available total length of growing period, and (ii) how well crop water requirements are met by growing period quality parameters (e.g., ratio of actual over potential evapotranspiration (ET_a/ET_m), or type of growing periods). Yield losses directly resulting from moisture constraints are quantified through adjustments of both the leaf area index and harvest index. For example, if the crop growth cycle is curtailed due to the length of growing period being insufficient, the leaf area index (LAI) is reduced proportionately relative to the LAI of the normal growth cycle considered. When the yield formation period is curtailed due to the growing period being shorter, the harvest index (Hi) is reduced proportionately in relation to the standard Hi of the reference yield formation period.

Losses in marketable value of the produce due to poor quality in yield as influenced by incomplete yield formation, however, cannot be accounted for in the biomass and yield calculations. These and other losses have been evaluated separately and are referred to as *agro-climatic constraints*.

4.3.4 Agro-climatic constraints

Matching the climatic characteristics by grid-cell with the crop temperature profile requirements and the calculation of net biomass and yield provides quantification of crop production that can be anticipated under conditions that are essentially free from soil constraints but also from agro-climatic constraints.

Agro-climatic constraints cause direct or indirect losses in the yield and quality of produce. Yields losses in a rain-fed crop due to agro-climatic constraints have been formulated based on principles and procedures proposed in FAO (1978-81a). For details of the conditions that are influencing yield losses and a listing of the agro-climatic constraint parameters for all the crop/LUTs considered, reference can be made to Appendix VIII.

In the present study, covering also temperate and boreal environments, one additional category of agro-climatic constraints has been added to the four categories in the original study. This fifth so-called 'e' constraint covers yield losses due to the occurrence of early or late frosts. The five categories are:

- (a) yield losses due to water-stress constraints on crop growth (e.g., rainfall variability);
- (b) yield losses due to the effect of pests, diseases and weed constraints on crop growth;

- (c) yield losses due to water-stress, pest and diseases constraints on yield components and yield formation of produce (e.g., affecting quality of produce);
- (d) yield losses due to workability constraints (e.g., wetness rendering produce handling difficulties); and
- (e) yield losses due to occurrence of early or late frosts.

The availability of historical rainfall data has made it possible to derive the effect of rainfall variability through year-by-year calculation of yield losses due to water stress. Therefore the ‘a’ constraint, related to rainfall variability is no longer applied. However the ‘a’ constraint has been retained in the agro-climatic constraints database for use with data sets containing average rainfall data and for comparison with results of the presently used year-by-year analysis.

The ‘b’, ‘c’ and ‘d’ constraints are related to wetness and the ratings of these constraints have been linked to the LGP. It appears however, that in different climate zones, wetness conditions, traditionally expressed as P/ET_o ratios, vary considerably for similar LGPs. Long LGPs with relatively low P/ET_o ratios occur generally in subtropical, temperate and boreal zones, while relatively high ratios occur in the tropics.

To account for these significant differences in *wetness* conditions of long LGPs (> 225 days), agro-climatic constraints have been related to P/ET_o ratios by calculating *equivalent LGPs*, i.e., adjustments where P/ET_o ratios were below average. The equivalent LGPs are then used in the application of the ‘b’, ‘c’, and ‘d’ constraints. Table 9 presents an example of agro-climatic constraints for winter wheat. For irrigated production only the agro-climatic constraints related to excess wetness apply.

Table 9 Agro-climatic constraints for winter wheat

SUBTROPICS, TEMPERATE AND BOREAL												
Growth	40 days pre-dormancy + 120 days post-dormancy											
LGP _{t=10}	60-89	90-	120-	150-	180-	210-	240-	270-	300-	330-	365 ⁻	365 ⁺
Low inputs												
a*	50	50	25	25	0	0	0	0	0	0	0	0
b	0	0	0	0	0	0	25	25	25	25	25	25
c	25	25	25	0	0	0	0	0	25	25	50	50
d	0	0	0	0	0	0	0	0	0	25	50	50
Intermediate Inputs												
a	50	50	25	25	0	0	0	0	0	0	0	0
b	0	0	0	0	0	0	0	25	25	25	25	25
c	25	25	25	0	0	0	0	0	25	25	50	50
d	0	0	0	0	0	0	0	0	0	25	50	50
High inputs												
a	50	50	25	25	0	0	0	0	0	0	0	0
b	0	0	0	0	0	0	0	0	25	25	25	25
c	25	25	0	0	0	0	0	0	0	25	25	50
d	0	0	0	0	0	0	0	25	25	25	50	50
LGP _{t=10}	60-89	90-	120-	150-	180-	210-	240-	270-	300-	330-	365	
All input levels												
e	100	50	25	0	0	0	0	0	0	0	0	

* The ‘a’ constraint (yield losses due to rainfall variability) is not applied in the current assessment. This constraint has become redundant due to explicit quantification of yield variability through the application of historical rainfall data sets.

The application of the agro-climatic constraints to the combined results of temperature suitability and the biomass and yield calculations (see previous Sections) provides agro-

climatic suitabilities. Plates 18 and 19 present examples of agro-climatic suitability maps for rain-fed and rain-fed plus irrigated wheat production at the high level of inputs.

4.4 Growing period suitability for water-collecting sites

In water-collecting sites substantially more water can be available to plants as compared to upland situations. Water-collecting sites are difficult to locate in a global study but can be approximately determined on the basis of prevalence of specific soil types. Fluvisols¹⁶ and to a lesser extent Gleysols¹⁷ are typically representing the flat terrain of alluvial valleys and other water-collecting sites.

The cultivation of Fluvisols (under unprotected natural conditions) is determined by frequency, duration and depth of flooding. The flooding attributes are generally controlled by external factors such as a river's flood regime which in turn is influenced by hydrological features of the catchment area and catchment/site relations, rather than by the amount of 'on site' precipitation.

Therefore, with the exception of wetland crops, the cultivation of these soils is mainly confined to post-flood periods, with crops growing on residual soil moisture. The flooding regime in arid and semi-arid zones is erratic. Some years, severe flash floods may occur, in other years no floods occur at all. In sub-humid and humid zones flooding is more regular but duration and depth of flooding may vary widely from year to year.

Gleysols are not directly affected by river flooding. These soils are however frequently situated in low-lying water-collecting sites and when not artificially drained, the Gleysols may be subject to water-logging or even inundation as result from combinations of high groundwater tables and ponding rainwater. In arid and semi-arid areas these soils are cultivated in the later part and after rainy seasons; the crops grow and mature on residual soil moisture. In sub-humid and humid areas Gleysols without artificial drainage often remain waterlogged for extensive periods, rendering them unsuitable for cultivation of dryland crops.

On both, Fluvisols and Gleysols, crops of short duration that are adapted to growing and producing yields on residual soil moisture and which are tolerant to flooding, water-logging and high groundwater tables, can be found producing satisfactorily outside the growing period defined by the local rainfall regime. Therefore, a separate crop suitability classification for water-collecting sites is required. In compiling this classification, the logic of the original AEZ study (FAO, 1978-81a) has been followed. This includes accounting for crop-specific tolerances to excess moisture (high ground-water, water-logging and flooding/inundation) and the use of available estimates of flooding regimes of the Fluvisols. Since Gleysols are mostly, but not necessarily, subjected to water-logging and inundation just like the 'natural Fluvisols', it was decided to treat Gleysols with terrain-slopes of less than 2% the same as Fluvisols.

In many parts of the world the flooding of Fluvisols is increasingly being controlled with dikes and other protection means. Fluvisols, in protected conditions, do not benefit additional water supply and regular fresh sediment deposits, nor do they suffer from flooding. The moisture regime of Fluvisols under these protected conditions is similar to other soils and

¹⁶ Fluvisols are by definition flooded by rivers. Fluvisols are young soils where sedimentary structures are clearly recognizable in the soil profile.

¹⁷ Gleysols are generally not flooded by rivers. However, the soil profiles indicate regular occurrence of high groundwater tables through reduction (gley) features. Low-lying Gleysols may be ponded/water-logged by high groundwater and rainfall during the rainy season.

therefore protected Fluvisols are treated according to the procedures used for crops in upland conditions.

In a similar way, Gleysols may be artificially drained, thereby diminishing a major limitation for the cultivation of these soils. For areas where the Gleysols have been drained, a revised (i.e., less severe) set of soil ratings is used and the rule for natural Fluvisols is not applied.

Since spatial details of the occurrence of protected Fluvisols and artificial drainage of Gleysols are not available at the global scale these factors are assumed to be linked to the level of inputs/management. The application of Fluvisol suitability ratings and soil unit suitability ratings of artificially drained Gleysols are presented below:

	Fluvisols		Gleysols	
	natural	protected	natural	artificially drained
RAIN-FED				
High level inputs	no	yes	no	yes
Intermediate level inputs	50%	50%	50%	50%
Low level inputs	yes	no	yes	no
IRRIGATION				
High level inputs	no	yes	no	yes
Intermediate level inputs	50%	50%	50%	50%

The moisture suitability ratings devised for unprotected Fluvisols and Gleysols without artificial drainage are organized in ten groups of crops with comparable growth cycle lengths and similar tolerances to high groundwater levels, water-logging and flooding. The rating tables are presented in Appendix IX.

4.5 Agro-edaphic suitability analysis

Adequate agricultural exploitation of the climatic potentials and maintenance of land productivity largely depend on soil fertility and the management of soils on an ecologically sustained basis. Soil fertility is concerned with the ability of the soil to retain and supply nutrients and water in order to enable crops to maximally utilize the climatic resources of a given location. The fertility of a soil is determined by both its physical and chemical properties. An understanding of these factors and insight in their interrelations is essential to the effective utilization of climate, terrain and crop resources for optimum use and production.

From the basic soil requirements of crops, a number of soil characteristics have been established related to crop yield response. For most crops and cultivars, optimal, sub-optimal, marginal and unsuitable levels of these soil characteristics are known and have been quantified. Beyond critical ranges, crops cannot be expected to yield satisfactorily unless special precautionary management measures are taken. Soil suitability classifications are based on knowledge of crop requirements, of prevailing soil conditions, and of applied soil management. In other words, soil suitability classifications quantify in broad terms to what extent soil conditions match crop requirements under defined input and management circumstances. For a global study this necessitates expert judgement and a semi-quantitative approach.

4.5.1 Soil suitability evaluation for rain-fed crop production

FAO's agro-edaphic suitability classification used in AEZ is to a large extent based on experience documented by Prof. C. Sys and others (FAO, 1978-81a; Sys and Riquier, 1980; FAO, 1984b; FAO, 1985; Nachtergaele, 1988; Sys, 1990; Sys *et al.*, 1993). The agro-edaphic suitability classification has been intensively used by FAO and other organizations, at various scales in many countries and regions; it passed through several international expert consultations, and hence it constitutes the most recent consolidation of expert knowledge. In this system a suitability rating is proposed for each soil unit, by individual crops at three defined levels of inputs and management circumstances. The agro-edaphic suitability rating is based on a comparison of soil requirements of crops and prevailing edaphic conditions. Data available from various sources have been summarized by Sys *et al.* (1993).

The source of soil information is primarily the digital version of the FAO/Unesco *Soil Map of the World* (FAO, 1995c). A tabulation of the soil ratings by FAO '74 soil unit for all crop/LUTs considered in GAEZ is presented in Appendix X. Soil phase suitability ratings are listed in Appendix XI. Modifications of soil suitability ratings for soil units with coarse textures are treated according to procedures presented in FAO (1978-81a).

4.5.2 Terrain suitability evaluation for rain-fed crop production

The influence of topography on agricultural land use is manifold. Farming practices are by necessity adapted to terrain slope, slope aspect, slope configuration and micro-relief. For instance, steep irregular slopes are not practical for mechanized cultivation, while these slopes might very well be cultivated with adapted machinery and hand tools.

Sustainable agricultural production on sloping land is concerned with the prevention of erosion of topsoil and decline of fertility. Usually this is achieved by combining special crop management and soil conservation measures. Slopes cultivated with crop/LUTs providing inadequate soil protection and without sufficient soil conservation measures, cause a considerable risk of accelerated soil erosion. In the short term, cultivation of slopes might lead to yield reductions due to loss of applied fertilizer and fertile topsoil. In the long term, this will result in losses of land productivity due to truncation of the soil profile and consequently reduction of natural soil fertility and of available soil moisture.

Rain-fed annual crops are the most critical to cause topsoil erosion, because of their particular cover dynamics and management. The terrain-slope suitability rating used in the Global AEZ study captures the factors described above which influence production and sustainability. This is achieved through: (i) defining for the various crop/LUTs permissible slope ranges for cultivation, by setting maximum slope limits; (ii) for slopes within the permissible limits, accounting for likely yield reduction due to loss of fertilizer and topsoil, and (iii) distinguishing among farming practices ranging from manual cultivation to fully mechanized cultivation.

Ceteris paribus, i.e., under similar crop cover, soil erodibility and crop and soil management conditions, soil erosion hazards largely depend on amount and intensity of rainfall. Data on rainfall amount is available on a monthly basis in the 0.5 degree latitude/longitude climate databases. Rainfall intensity or energy, as is relevant for soil erosion, is not estimated in these data sets.

To account for clearly existing differences in both amount and within-year distribution of rainfall, use has been made of the modified Fournier index (*Fm*), which reflects the combined effect of rainfall amount and distribution (FAO/UNEP, 1977), as follows:

$$Fm = 12 \sum_{i=1}^{12} \frac{p_i^2}{Pann}$$

where:

p_i = precipitation of month i

$Pann$ = total annual precipitation

When precipitation is equally distributed during the year, i.e., in each month one-twelfth of the annual amount is received, then the value of Fm is equal to $Pann$. On the other extreme, when all precipitation is received within one month, the value of Fm amounts to twelve times $Pann$. Hence, Fm is sensitive to both total amount and distribution of rainfall and is limited to the range of $Pann \leq Fm \leq 12 Pann$. The Fm index has been calculated for all 0.5 degree grid-cells of the climatic inventory. The results have been grouped in six classes, namely: $Fm < 1300$, 1300-1800, 1800-2200, 2200-2500, 2500-2700, and $Fm > 2700$.

Slope ratings are defined for the seven slope range classes used in the land resources database, namely: 0-2% flat, 2-5% gently sloping, 5-8 % undulating, 8-16% rolling, 16-30% hilly, 30-45% steep, and > 45% very steep. The following suitability rating classes are employed:

S1	Optimal conditions
S2	Sub-optimal conditions
S1/S2	50% optimal and 50% sub-optimal conditions
S2/N	50% sub-optimal and 50% not suitable conditions
N	Not suitable conditions

Table 10 presents terrain-slope ratings for rain-fed conditions for eight crop groups at three levels of inputs and management in grid-cells with rainfall such that the level of the Fournier index $Fm < 1300$. Additional ratings, for levels of the index $Fm > 1300$, are listed in Appendix XIV.

Table 10 Terrain-slope ratings for rain-fed conditions ($Fm < 1300$)

High Inputs

Slope Gradient Classes	0-2 %	2-5%	5-8%	8-16%	16-30%	30-45%	> 45%
Annuals 1	S1	S1	S1	S1/S2	N	N	N
Annuals 2	S1	S1	S1	S1/S2	N	N	N
Wetland rice	S1	S1/S2	S2/N	N	N	N	N
Sugarcane	S1	S1	S1/S2	S2/N	N	N	N
Olive	S1	S1	S1	S2	S2/N	N	N
Perennials	S1	S1	S1	S2	N	N	N
Pasture	S1	S1	S1	S1	S2/N	N	N
Forage legumes	S1	S1	S1	S1/S2	N	N	N

Intermediate Inputs

Slope Gradient Classes	0-2 %	2-5%	5-8%	8-16%	16-30%	30-45%	> 45%
Annuals 1	S1	S1	S1	S1/S2	S2	N	N
Annuals 2	S1	S1	S1	S1/S2	S2	N	N
Wetland rice	S1	S1/S2	S2	N	N	N	N
Sugarcane	S1	S1	S1/S2	S2/N	N	N	N
Olive	S1	S1	S1	S1/S2	S2	N	N
Perennials	S1	S1	S1	S2	S2/N	N	N
Pasture	S1	S1	S1	S1	S1/S2	S2/N	N
Forage legumes	S1	S1	S1	S1	S1/S2	S2/N	N

Low Inputs

Slope Gradient Classes	0-2 %	2-5%	5-8%	8-16%	16-30%	30-45%	> 45%
Annuals 1	S1	S1	S1	S1	S2	N	N
Annuals 2	S1	S1	S1	S1/S2	S2	N	N
Wetland rice	S1	S1/S2	S2	N	N	N	N
Sugarcane	S1	S1	S1S2	S2/N	N	N	N
Olive	S1	S1	S1	S1/S2	S2	S2/N	N
Perennials	S1	S1	S1	S2	S2/N	N	N
Pasture	S1	S1	S1	S1	S1/S2	S2/N	N
Forage legumes	S1	S1	S1	S1	S1/S2	S2/N	N

Crop Groups: Annuals 1: wheat, barley, rye;
 Annuals 2: maize, sorghum, pearl millet, foxtail millet, white potato, sweet potato, phaseolus bean, chickpea, cowpea, soybean and groundnut, sunflower, cotton, sugar beet, rape;
 Perennials: cassava, oil palm, banana, plantain.

4.5.3 Soil and terrain suitability evaluation for irrigated crop production

The evaluation procedures for gravity irrigation suitability cover the dryland crops and wetland rice, at both intermediate and high levels of management and input circumstances. Three important assumptions have been made in setting up the procedures¹⁸: firstly, water resources of good quality are available; secondly, irrigation infrastructure is in place; and thirdly, the crop-specific soil limitations for rain-fed production (such as limitations imposed by soil rooting conditions, soil nutrient availability and soil nutrient retention capacity, soil toxicity, soil salinity, soil alkalinity, and calcium carbonate and gypsum content) also apply to irrigation. For irrigation these limitations are assumed to be similar or more severe. Note, however, that the Global AEZ assessment does not provide a quantification of irrigation water availability. Nevertheless, it can generate useful information for integrated analysis at the watershed level.

The following land and soil characteristics have been interpreted specifically for the irrigation suitability classification: topography; soil drainage; soil texture; surface and sub-surface stoniness; calcium carbonate levels; gypsum status; and salinity and alkalinity conditions. The main literature sources used in the interpretation include Sys *et al.* (1993), Sys and Riquier (1980), FAO (1985), FAO (1996), FAO (1976b), FAO/Unesco (1974), and FAO/Unesco/ISRIC (1990).

¹⁸ In arid and hyperarid areas only Fluvisols, Gleysols and soils with phreatic phase have been considered for the assessment of irrigation suitability.

Topography

The dominant topographic factor governing the suitability of an area for gravity or sprinkler irrigation is the terrain slope. Other topographic factors, such as micro-relief, have partly been accounted for in the soil unit and soil phase suitability classifications. Permissible slopes for irrigation depend on type of irrigation systems and assumed level of inputs and management.

Gravity irrigation (basin, border, and furrow systems) is suitable for a large range of crops provided it is managed properly. It is used for terrain slopes up to 5 percent. For ‘non-row crops’ such as wheat, barley, pasture and forage legumes, slopes up to 10 percent can be used with special systems such as corrugations. At these steeper slopes irrigation efficiency is diminished due to poor uniformity of the water distribution, leading to irregular stands of crops. Therefore, slopes between 5 and 10 percent are classified as sub-optimal for all types of gravity irrigation.

Table 11 Terrain-slope ratings for gravity irrigation

High Inputs

Slope Gradient Classes	0-2 %	2-5%	5-8%	8-16%	16-30%	30-45%	> 45%
Annuals 1	S1	S1	S2/N	N	N	N	N
Annuals 2	S1	S1/S2	S2/N	N	N	N	N
Wetland rice	S1	S1/S2	N	N	N	N	N
Sugarcane	S1	S1/S2	S2/N	N	N	N	N
Olive	S1	S1/S2	S2/N	N	N	N	N
Perennials	S1	S1/S2	S2/N	N	N	N	N
Pasture	S1	S1	S2/N	N	N	N	N
Forage legumes	S1	S1	S2/N	N	N	N	N

Intermediate Inputs

Slope Gradient Classes	0-2 %	2-5%	5-8%	8-16%	16-30%	30-45%	> 45%
Annuals 1	S1	S1	S1/S2	S2/N	N	N	N
Annuals 2	S1	S1/S2	S2/N	N	N	N	N
Wetland rice	S1	S1/S2	N	N	N	N	N
Sugarcane	S1	S1/S2	S2/N	N	N	N	N
Olive	S1	S1/S2	S2/N	N	N	N	N
Perennials	S1	S1/S2	S2/N	N	N	N	N
Pasture	S1	S1	S1/S2	S2/N	N	N	N
Forage legumes	S1	S1	S1/S2	S2/N	N	N	N

Crop Groups: Annuals 1: wheat, barley, rye;
 Annuals 2: maize, sorghum, pearl millet, foxtail millet, white potato, sweet potato, phaseolus bean, chickpea, cowpea, soybean and groundnut, sunflower, cotton, sugar beet, rape;
 Perennials: cassava, oil palm, banana, plantain.

Sprinkler irrigation systems include many types. They are generally more efficient than gravity systems but also much more expensive, and they require special management skills. Sprinklers can be used on somewhat steeper slopes than the gravity systems. However, some of the larger central pivot systems can only be used on flat or almost flat terrain. Small-scale systems are more suitable on sloping land. For perennial or well established pastures well adapted systems may be used on slopes up to 24 percent. For annual crops, serious erosion

risk starts at about 10-12 percent slopes, depending on soil erodibility, ground cover, and management. Sprinkler irrigation is obviously not suitable for wetland crops.

Tables 11 and 12 present terrain-slope suitability ratings, respectively for gravity and sprinkler irrigation systems, for eight groups of crops at high and intermediate levels of inputs. The suitability rating classes are the same as for rain-fed conditions.

Table 12 Terrain-slope ratings for sprinkler irrigation

High Inputs

Slope Gradient Classes	0-2 %	2-5%	5-8%	8-16%	16-30%	30-45%	> 45%
Annuals 1	S1	S1	S1/S2	S2/N	N	N	N
Annuals 2	S1	S1	S1/S2	S2/N	N	N	N
Wetland rice	N	N	N	N	N	N	N
Sugarcane	S1	S1	S1/S2	S2/N	N	N	N
Olive	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Perennials	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Pasture	S1	S1	S1	S1/S2	S2/N	N	N
Forage legumes	S1	S1	S1/S2	S2/N	N	N	N

Intermediate Inputs

Slope Gradient Classes	0-2 %	2-5%	5-8%	8-16%	16-30%	30-45%	> 45%
Annuals 1	S1	S1	S1/S2	S2/N	N	N	N
Annuals 2	S1	S1	S1/S2	S2/N	N	N	N
Wetland rice	N	N	N	N	N	N	N
Sugarcane	S1	S1	S1/S2	S2/N	N	N	N
Olive	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Perennials	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Pasture	S1	S1	S1	S1/S2	S2/N	N	N
Forage legumes	S1	S1	S1/S2	S2/N	N	N	N

Crop Groups: Annuals 1: wheat, barley, rye;
 Annuals 2: maize, sorghum, pearl millet, foxtail millet, white potato, sweet potato, phaseolus bean, chickpea, cowpea, soybean and groundnut, sunflower, cotton, sugar beet, rape;
 Perennials: cassava, oil palm, banana, plantain.

Soil texture

Soil texture provides a measure for permeability and to some extent, for water retention capacity. Soils with potentially high percolation losses and soils with low water retention capacity, e.g., Vitric Andosols, Arenosols, Podzols and all soils with coarse textures have been considered not suited for gravity irrigation. For medium and fine textured soils excessive percolation and low water-retention capacities are less relevant. However for Acrisols, Nitosols and Ferralsols the irrigation suitability ratings are slightly different as compared to rainfed conditions, because of their specific clay mineralogy, resulting in relatively low water-retention capacity and slightly higher percolation losses. The modifications related to texture/clay mineralogy are summarized in Table 13.

Table 13 Soil texture/clay mineralogy limitations

Major Soil Unit		Soil Unit	Suitability	
FAO '74	FAO '90		Dryland Crops	Wetland Rice
Acrisols (A)	Acrisols (AC)	all units	S1/S2	S2
Ferralsols (F)	Ferralsols (FR)	all units	S1/S2	S2
Nitisols (N)	Nitisols (NT)	all units	S1/S2	S2
Podzols (P)	Podzols (PZ)	all units	N	N
Arenosols (Q)	Arenosols (AR)	all units	N	N
Andosols (T)	Andosols (AN)	Tv, ANz	N	N
n.a.	Alisols (AL)	all units	S1/S2	S2
n.a.	Plinthosols (PT)	all units	S1/S2	S2

Soil drainage

Irrigation of dryland crops requires well drained soils to assure aeration and to avoid the danger of secondary salinization. Drainage conditions depend on depth and quality of groundwater. At present, this can not be assessed on regional and global scales due to lack of systematic data. Soil drainage quantification, however, is available for the soil units of the FAO '74 legend (FAO, 1995c). For wetland rice and dryland crops drainage requirements under irrigation are quite different as compared to rain-fed conditions. Therefore, the following modifications to rain-fed suitability ratings were adopted in GAEZ (see Table 14).

Table 14 Soil drainage limitations

LUT	Soil Drainage Class	Suitability
Wetland Rice	P	S1
	VP, I, MW, W	S2
	SE, E	N
Dryland crops	W	S1
	MW	S1/S2
	I, P	S2
	VP, SE, E	N

Drainage Classes: VP very poor P poor I imperfectly
 MW moderately well W well SE somewhat excessively E excessively

Soil depth and soil stoniness

Under irrigated conditions soil depth affects drainage, aeration and water retention properties. Deep soils favor drainage and are therefore optimal for irrigation of dryland crops. Soils with impermeable layers favor maintenance of flooding conditions for wetland rice. Shallow soils such as Rendzinas (Rendzic Leptosols) and Rankers (Umbric Leptosols) and soils with phases implying a reduction in soil depth have been reviewed and adjusted for irrigated conditions.

Surface stoniness affects soil workability. In addition, subsurface stoniness reduces water-holding capacity and increases infiltration rates. It is assumed that a level of more than 40 volume percent of coarse materials will markedly influence the water-balance in the soil profile (Sys and Riquier, 1980). To cater for these constraints specifically affecting irrigation suitability, the soil phase suitability ratings for petric (skeletal) and stony phases (rudic) in FAO legends have been adjusted from the rain-fed ratings. The soil phase ratings for irrigated crop production are presented in Appendix XI.

Calcium carbonate

Calcium carbonate in the form of free lime in the soil profile affects soil structure and interferes with infiltration and evapotranspiration processes. It influences both the soil moisture regime and availability of nutrients. This, however, applies equally to rain-fed and irrigated cropping. Therefore, no changes are required to the crop-specific limitations as established for rain-fed cropping.

Gypsum

Gypsum interferes with water absorption and availability. As consequence of the solubility of gypsum in water, so-called dissolution depressions can be formed as a result of the application of irrigation water to gypsiferous soils. This renders soils with high gypsum content unsuitable for irrigation. These gypsiferous soils and soil phases are listed below in Table 15.

Table 15 Soil units with gypsum limitations

Gypsiferous Soil Units		Gypsiferous Soil Phases	
FAO 1974	FAO 1990	FAO 1974	FAO 1990
Yy, Yl, Xy, Xl, Kl, Kk, Ck, Cl, and Bk	GY, GYk, GYl, GYh, KSy, RGy, SCy, SNy	Petrogypsic	Yermic

Salinity and alkalinity

Irrigation in semi-arid and arid regions requires careful soil drainage (natural and/or artificial) to avoid irrigation-induced secondary salinization. It is assumed that, where so required, appropriate drainage systems are in place and that irrigation water is non-saline. In this case no changes are necessary to the crop-specific suitability ratings as used for rain-fed cropping.

Alkalinity, expressed as sodium saturation, influences the structure stability of soils, which in turn affects infiltration rates and aeration of soils. The alkalinity (sodicity) constraints are equally important for rain-fed and irrigated conditions. Therefore, the crop-specific soil unit and soil phase ratings evaluated for rain-fed conditions remain unchanged for irrigated cropping.

4.6 Fallow period requirements

In their natural state, many soils, in particular in the tropics, cannot be continuously cultivated without undergoing degradation. Such degradation is marked by a decrease in crop yields and a deterioration of soil structure, nutrient status and other physical, chemical and biological attributes. Under traditional low input farming systems, this deterioration is kept in check by alternating some years of cultivation with periods of fallow. The length of the necessary rest period is dependent on inputs applied, soil and climate conditions, and crops. Hence, the main reason for incorporating fallow into crop rotations is to enhance sustainability of production through maintenance of soil fertility.

Regeneration of nutrients and maintenance of soil fertility under low input cultivation is achieved through natural bush or grass fallow. At somewhat higher inputs to soils, soil fertility is maintained through fallow, which may include for a portion of time a grass, grass-legume ley or a green-manure crop. Factors affecting changes in soil organic matter are reviewed in Nye and Greenland (1960) and Kowal and Kassam (1978). They include temperature, rainfall, soil moisture and drainage, soil parent material, and cultivation

practices. The fallow factors used in the present Global AEZ land potential are based on earlier work done in the context of FAO's regional assessments (Young and Wright, 1980) and the Kenya AEZ study (FAO/IIASA, 1991).

The fallow factors have been established by main crop groups and environmental conditions. The crop groups include cereals, legumes, roots and tubers, and a miscellaneous group consisting of long term annuals/perennials. Fallow requirements have been assumed to be negligible for olive and oil palm. The environmental frame consists of individual soil units, thermal regimes and moisture regimes. The thermal regimes are expressed in terms of annual mean temperatures of > 25°C, 20-25°C, 15-20°C and <15°C. The moisture regimes are made up of five broad LGP ranges:<90 days, 90-120 days, 120-180 days, 180-270 days, and > 270 days.

Appendix XII presents fallow-land requirements by thermal and moisture regimes imposed to maintain soil fertility. This factor is expressed as percentage of time during the fallow-cropping cycle the land must be under fallow. For Fluvisols and Gleysols fallow factors are lower because of their special moisture and fertility conditions.

At high levels of inputs and management fallow requirements are uniformly set at 10%. At intermediate level of inputs the fallow requirements are set at one third of the levels required under low level of inputs. In the present study the fallow requirement factors have been applied for the estimations of annually available arable land.

4.7 Multiple cropping zones for rain-fed crop production

In the GAEZ crop suitability analysis, the LUTs considered refer to single cropping of sole crops, i.e., each crop is presumed to occupy the land only once a year and in pure stand. Consequently, in areas where the growing periods are sufficiently long to allow more than one crop to be grown in the same year or season, single crop yields do not reflect the full potential of total time and space available per unit area of land for rain-fed production.

To assess the multiple cropping potential, a number of multiple cropping zones have been defined through matching both growth cycle and temperature requirements of individual suitable crops with time available for crop growth. For rain-fed conditions this period is approximated by the LGP, i.e., the number of days during which both temperature and moisture conditions permit crop growth.

For the definition of multiple cropping zones four types of crops are distinguished: thermophilic crops requiring warm temperatures, cryophilic crops performing best under cool and moderately cool conditions, hibernating crops, and wetland crops with specific water requirements. Furthermore, the crops are subdivided according to growth cycle length, namely of less or more than 120 days duration, respectively. According to the above criteria, the following nine zones were classified and mapped (see Plate 20):

- A.** *Zone of no cropping* (too cold or too dry for rain-fed crops)
- B.** *Zone of single cropping*
- C.** *Zone of limited double cropping* (relay cropping; single wetland rice may be possible)
- D.** *Zone of double cropping* (sequential cropping; wetland rice not possible)
- E.** *Zone of double cropping* (sequential cropping; one wetland rice crop possible)
- F.** *Zone of limited triple cropping* (partly relay cropping; no third crop possible in case of two wetland rice crops)

- G.** *Zone of triple cropping* (sequential cropping of three short-cycle crops; two wetland rice crops possible)
- H.** *Zone of triple rice cropping* (sequential cropping of three wetland rice crops possible)

Delineation of multiple cropping zones for rain-fed conditions is solely based on agro-climatic attributes calculated during AEZ analysis. The following attributes were used in the definition of cropping zones:

LGP	length of growing period, i.e., number of days when temperature and soil moisture permit crop growth.
LGP _{t=5}	number of days with mean daily temperatures above 5°C.
LGP _{t=10}	number of days with mean daily temperatures above 10°C.
TS _{t=0}	accumulated temperature (degree-days) on days when mean daily temperature ≥ 0°C.
TS _{t=10}	accumulated temperature (degree-days) on days when mean daily temperature ≥ 10°C.
TS-G _{t=5}	accumulated temperature during growing period when mean daily temperature ≥ 5°C.
TS-G _{t=10}	accumulated temperature during growing period when mean daily temperature ≥ 10°C.

Table 16 and 17 summarize the delineation criteria for multiple cropping zones under rain-fed conditions in respectively the tropics and the subtropics/temperate zones.

Table 16 Delineation of multiple cropping zones under rain-fed conditions in the tropics

Zone	LGP	LGP _{t=5}	LGP _{t=10}	TS _{t=0}	TS _{t=10}	TS-G _{t=5}	TS-G _{t=10}
A ¹⁹⁾	—	—	—	—	—	—	—
B ²⁰⁾	≥ 45	≥120	≥90	≥1600	≥1000	—	—
C ²¹⁾	≥220	≥220	≥	≥5500		≥	≥
	≥200	≥200	≥120	≥6400	n.a.	≥3200	≥2700
	≥180	≥200	≥	≥7200		≥	≥
D ²²⁾	≥270	≥270	≥	≥5500		≥	≥
	≥240	≥240	≥165	≥6400	n.a.	≥4000	≥3200
	≥210	≥240	≥	≥7200		≥	≥
E	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
F	≥300	≥300	≥240	≥7200	≥7000	≥5100	≥4800
G	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
H	≥360	≥360	≥360	≥7200	≥7000	—	—

Table 17 Delineation of multiple cropping zones under rain-fed conditions in subtropics and temperate zones

Zone	LGP	LGP _{t=5}	LGP _{t=10}	TS _{t=0}	TS _{t=10}	TS-G _{t=5}	TS-G _{t=10}
A ¹⁹⁾	—	—	—	—	—	—	—
B ²⁰⁾	≥ 45	≥120	≥90	≥1600	≥1000	—	—
C	≥180	≥200	≥120	≥3600	≥3000	≥3200	≥2900
D	≥210	≥240	≥165	≥4500	≥3600	≥4000	≥3200
E	≥240	≥270	≥180	≥4800	≥4500	≥4300	≥4000
F	≥300	≥300	≥240	≥5400	≥5100	≥5100	≥4800
G	≥330	≥330	≥270	≥5700	≥5500	—	—
H	≥360	≥360	≥330	≥7200	≥7000	—	—

¹⁹⁾ Applies if conditions for zone B ('single cropping') are not met.

²⁰⁾ The program tests if at least one of the crop/LUTs is agro-climatically suitable in the respective grid-cell.

^{21), 22)} Refers to, respectively, high-land, mid high-land, and lowland areas in the tropics.

4.8 Review of results

4.8.1 Stepwise review of suitability analysis procedures

Crop suitability is a result of both agro-climatic and agro-edaphic evaluation. The combination of the agro-climatic suitabilities with the agro-edaphic suitabilities is based on the fact that the former results assume ideal soil and terrain conditions, while the latter evaluation assumes ideal agro-climates. In fact, the results of the agro-climatic suitabilities are successively modified, according to edaphic suitabilities, to provide overall crop suitability.

The calculation procedures have been grouped into five steps:

- (1) Climate data analysis
- (2) Crop-specific agro-climatic assessment and potential biomass calculation
- (3) Application of agro-climatic constraints
- (4) Edaphic assessments
- (5) Various applications (e.g., calculation of land with cultivation potential)

Step 1 calculates and organizes climate-related parameters for each grid-cell, i.e.,

- Altitude.
- Latitudinal climate
- Presence of cold break
- Continentality index
- Mean annual temperature
- Mean annual minimum temperature
- Mean annual maximum temperature
- Temperature profile: number of days in intervals of five degree centigrade steps from <-5°C to > 30°C separately for periods of increasing and decreasing temperatures
- Thermal growing periods: number of days >0°C, >5°C, >10°C
- Begins and ends of thermal growing periods
- Accumulated temperature during thermal growing periods
- Mean temperature during thermal growing periods
- Aridity index (precipitation over reference evapotranspiration)
- Aridity index during growing period
- Total number of growing period days
- Number of growing period days when full crop water requirements of reference crop are met
- Total number of wet-days, i.e., growing period days with excess moisture
- Number of growing periods
- Begin and end of dormancy period
- Length of individual LGPs
- Number of days in each LGP when crop water requirements can be fully met.
- Number of days in each LGP with excess moisture
- Begin and end dates of each LGP
- Temperature profile during growing period
- Accumulated temperatures (above 0°C, 5°C, 10°C) during growing period
- Average temperature during growing period
- Multiple-cropping zones classification for rain-fed and irrigated conditions

Since all the above data is organized by grid-cell, maps of each item can be produced for spatial verification.

In **Step 2**, all the 154 LUTs (148 crop/LUTs and 6 grass/pasture legume LUTs) are “grown”. The LUTs are tested starting successively each day during the permissible window of time (separately determined for irrigated and rain-fed conditions). The highest obtained yield defines the optimal crop calendar of each LUT in each grid-cell. The CROPWAT methodology (FAO, 1992a) is used to run crop-specific water balances and to account for yield losses due to water deficits. Calculations are done seven times: once for irrigation conditions, and six times for rain-fed conditions assuming in the soil moisture balance calculations an available water-holding capacity (AWC) of respectively 150, 125, 100, 75, 50 and 15 mm/m. The following information is stored for each grid-cell after Step 2:

- Maximum attainable biomass and yield (determined by radiation and temperature)
- Estimated actual crop evapotranspiration (ETa)
- Accumulated crop water deficit during the growth cycle (i.e., ETo - ETa)
- Attainable water-limited biomass and yield

All these individual items can be reproduced in map form, for viewing and for spatial verification.

In **Step 3** specific multipliers are used to downgrade yields for what is defined in AEZ as agro-climatic constraints. This step is carried out separately to make the effect of the workability, pest and diseases, and other constraints transparent. The results of Step 3, agro-climatically attainable yields, are stored by crop/LUT for each grid-cell. The intermediate results of agro-climatic suitabilities, therefore, can be mapped for spatial verification.

Step 4 performs the edaphic assessment and combines the agro-climatic results in accordance with the soil information. The FAO digital soil map of the World (DSMW), with a grid-cell size of 5 arc-minutes latitude/longitude, is used for the assessment, defining soil characteristics (soil type, soil texture and soil phase) and proportions of different soils in each mapping unit. For terrain-slope conditions, a slope distribution was derived from the 30 arc-second GTOPO30 digital elevation database (EROS Data Center, 1998). The slope characterization has been aggregated to the grid-cells of the DSMW in terms of seven classes, as used in SOTER (van Engelen and Ting-tiang, 1993): 0-2%, 2-5%, 5-8%, 8-16%, 16-30%, 30-45% and > 45%. Soil and slope rules are applied separately for rain-fed and irrigated conditions. As a result, for each 5-minute grid-cell and each crop/LUT an expected yield and suitability distribution (5 classes VS, S, MS, mS and NS) regarding rain-fed and irrigation conditions are obtained. Results are stored separately for dryland and naturally flooded soils (Fluvisols, and Gleysols with 0-2 % slopes). The results have been mapped of which several examples can be found in the Appendix XV. Suitability maps of the single-crop/LUTs have been intensively used for spatial verification.

Step 5. The databases created in steps 1 to 4 can and have been used to derive additional characterizations and aggregations, such as:

- Calculation of land with cultivation potential is involving an aggregation over individual crop/LUTs to estimate how much land is potentially suitable for crop cultivation. Examples of results were presented in this chapter and have proven useful for spatial verification purposes.
- Tabulation of results by ecosystem type: the USGS 1km land cover data set was aggregated to twelve major ecosystems and subsequently to 5-minute DSMW grid-cells. The resulting ecosystem distribution was matched with the assessed land with cultivation potential in each DSMW grid-cell, providing information about what suitable extents are

under which current ecosystems. This information was useful to compare and verify, for example, the overlap between potential cultivable land and land shown as being currently in use for cropping.

- Quantification of climatic production risks by using historical time series of suitability results. For each crop/LUT and grid-cell this has resulted in information on average crop yield, number of crop failures, standard deviation of expected yields, ratio of average yield versus yield of average climate. In this way spatial distribution of climatic production risk can be mapped and verified.

As discussed above, the structure of the suitability analysis procedures allows step-wise review of results. As example of a verification sequence, a selection of intermediate results in map form for 120-days grain maize, grown under rain-fed conditions at high input level, are presented in Appendix XV:

Plate 21 (Step 1) Growing period days

Plate 22 (Step 2) Maximum attainable potential biomass and yield (determined by radiation and temperature)

Plate 23 (Step 2) Attainable (water limited) potential biomass and yield

Plate 24 (Step 3) Agro-climatically attainable yield potentials (including the effect of agro-climatic constraints)

Plate 25 (Step 4) Expected yields after application of edaphic constraints

Plate 26 (Step 5) Maximum expected yields potentials across all 13 grain-maize types

The results, obtained after completion of each of the above steps, have been used in the process of checking and validating the proper functioning of the various procedures. The intermediate and final results have been helpful for the verification against research data, crop statistics, expert knowledge, etc.

4.8.2 Confirmation of results

Various modes have been pursued for ‘ground-truthing’ and verifying results of the AEZ suitability analysis. Apart from consulting expert knowledge and agricultural research institutes, results have been systematically compared with research data and agricultural statistics. In particular the following activities have been conducted intensively by IIASA and FAO staff of ES and AG departments.

- Confirmation of estimated potential crop distribution and yields against quantitative and qualitative occurrence of these crops in national and sub-national agricultural statistics.
- Comparison of limits of AEZ potential crop distribution with limits to actual distribution of agricultural land (e.g., by comparison with spatial land use/land cover databases and crop distribution maps).

It should, however, be understood, that in the light of improved knowledge any part of the GAEZ suitability procedures and the model parameters will be scrutinized and may be subject to updating by FAO and IIASA. Also, the model and model parameters are expected to benefit refinement as result of follow-up applications.

5. RESULTS

In essence, the Global AEZ assessment has provided a comprehensive and spatially explicit database of crop production potential and related factors. The results are a valuable source of information and input to various global and regional applications. Examples of different types of results generated by Global AEZ are presented in the various sections of this chapter.

Section 5.1 provides data on occurrence and spatial distribution of climate, soil and terrain constraints to rain-fed crop production. Section 5.2 presents various results of the crop suitability analyses for rain-fed conditions and for rain-fed and/or irrigated conditions combined. Crop yields and sustainability of production are discussed in Section 5.3 in relation to differences between maximum attainable yields and long-term achievable yields. In Section 5.4 we present estimates of land with cultivation potential based on all cereal and non-cereal food and fiber crop/LUTs considered (i.e., from the list of 154 LUTs we excluded banana, oilpalm, olives, silage maize, alfalfa, grass legumes and grasses).

Section 5.5 highlights areas with high potential for irrigated crops vis-à-vis rain-fed crops. Furthermore, the production potential results are used in Section 5.6 to identify for individual grid-cells a 'best' cereal in terms of respectively agronomic suitability, food energy and gross value. Section 5.7 provides estimates of land productivity potential including multi-cropping. Section 5.8 deals with the comparison of estimated crop production potentials and land cover data. Finally, Section 5.9 discusses the sensitivity of regional crop production potential to climate change. Preliminary results of the suitability analysis for a number of temperature and rainfall sensitivity scenarios are presented.

All results discussed in the various sections of this chapter are available in digital formats; maps of respectively 5-minute and 30-minute latitude/longitude resolution, and tables (in form of spreadsheets) at different levels of aggregation, i.e., respectively at global, continental, regional and country levels.

5.1 Climate, soil and terrain constraints to rain-fed crop production

The classifications of soil and terrain constraints in Global AEZ for the application with FAO's Digital Soil Map of the World were briefly introduced in Section 3.3. Climate constraints are classified according to length of periods with cold temperatures and moisture limitations. Temperature constraints are related to the length of the temperature growing period ($LGP_{t=5}$), i.e., number of days with mean daily temperature above 5°C. An $LGP_{t=5}$ of less than 120 days is considered a severe constraint, while an $LGP_{t=5}$ of less than 180 days is considered as posing moderate constraints to crop production. Hyper-arid and arid moisture regimes ($LGP < 60$ days) are considered severe constraints, and dry semi-arid moisture regimes ($LGP 60-119$ days) as moderate constraints.

On the basis of currently available soil, terrain and climatic data, the Global AEZ assessment estimates that some 10.5 billion hectares of land, i.e., almost four-fifth of the global land surface (excluding Antarctica), suffer rather severe constraints for rain-fed crop cultivation. An estimated 13 percent is too cold, 27 percent is too dry, 12 percent is too steep, and some 65 percent is constrained by poor soil conditions. Note, percentages do not sum up to 100, because several constraints coincide in some locations. Table 18 presents the regional distribution of different types of severe constraints mostly inhibiting rain-fed crop production.

Table 19 gives a more detailed account of various kinds of land constraints for rain-fed crop production. The analysis concludes that only 3.5 percent of the land surface (excluding Antarctica) can be regarded to be entirely free of constraining factors. Only for some sub-

regions in Europe the share of essentially constraint-free conditions reaches 20 percent and more. Tables A1 to A22 in Appendix I present results aggregated by broad LGP classes separately for 22 major world regions. Plates 20 to 28 show the geographical distribution of climatic and soil/terrain constraints to rain-fed crop production.

Table 18 Severe environmental constraints²³ for rain-fed crop production

Region	Total extents (10 ⁶ ha)	Land with severe constraints for rain-fed cultivation of crops					
		Total with constraints		Too cold	Too dry	Too steep	Poor soils
		(10 ⁶ ha)	(%)	(%)	(%)	(%)	(%)
North America	2138.5	1774.7	83.0	35.9	13.9	10.4	69.3
Eastern Europe	171.0	68.0	39.8	0.0	0.0	5.9	38.7
Northern Europe	172.5	135.5	78.5	18.0	0.0	9.9	77.8
Southern Europe	131.6	63.6	48.3	0.7	0.1	31.0	44.3
Western Europe	109.5	56.9	51.9	0.6	0.0	13.5	49.4
Russian Federation	1674.1	1412.5	84.4	44.6	2.5	11.9	82.8
Caribbean	23.4	15.7	67.0	0.0	0.0	15.8	65.8
Central America	248.4	184.8	74.4	0.0	31.5	26.3	59.7
South America	1777.6	1251.8	70.4	0.5	10.6	7.5	63.6
Oceania	793.5	698.7	88.1	0.0	61.6	1.8	62.4
Polynesia	56.1	32.4	57.8	0.8	0.8	24.9	48.8
Eastern Africa	639.5	404.7	63.3	0.0	18.5	10.2	53.5
Middle Africa	657.1	515.0	78.4	0.0	13.1	3.3	72.6
Northern Africa	794.1	728.2	91.7	0.0	77.4	5.2	62.7
Southern Africa	266.4	210.6	79.0	0.0	56.9	14.4	43.1
Western Africa	633.0	469.2	74.1	0.0	50.9	0.8	50.5
Western Asia	433.0	382.6	88.4	0.0	74.5	16.4	53.3
Southeast. Asia	444.5	271.8	61.2	0.0	0.0	21.7	57.4
South Asia	671.8	475.4	70.8	2.5	33.7	22.8	57.9
East Asia	1112.3	911.4	81.9	16.6	33.8	26.5	63.0
Central Asia	414.4	382.0	92.2	2.5	78.4	10.0	78.1
Japan	37.2	21.9	58.8	0.0	0.0	35.9	54.4
DEVELOPING	8171.5	6235.5	76.3	2.7	34.4	12.8	60.9
DEVELOPED	5228.0	4231.8	80.9	29.6	15.8	10.2	70.7
WORLD TOTAL	13399.5	10467.3	78.1	13.2	27.1	11.8	64.7

²³ Extents of different constraint types are not additive as the occurrence of constraints may overlap.

Table 19 Climate, soil and terrain constraints for rain-fed crop production - world totals

Constraints			LGP 0 days CC	LGP 1-60 CC	LGP 60-119 C	LGP 120- 179	LGP 180- 269	LGP 270- 365	LGP 365+ C	Totals	
										(10 ⁶ ha)	(%)
Temperature	LGP _{t=5} > 180		2366.0	987.8	1011.3	984.3	2202.0	2109.6	268.0	9929.0	74.1
	LGP _{t=5} < 180	C	66.7	124.3	181.1	1331.2	0	0	0	1703.3	12.7
	LGP _{t=5} < 120	CC	319.9	257.0	1190.3	0	0	0	0	1767.2	13.2
Terrain slopes	0 - 8%		1723.8	759.8	1072.5	1165.8	1127.4	1235.2	160.8	7245.3	54.1
	8 - 16%	C	489.0	245.2	429.0	454.3	409.4	317.2	33.0	2377.1	17.7
	16 - 30%	C	354.6	196.0	480.4	419.5	395.6	313.6	42.0	2201.7	16.4
	> 30%	CC	185.2	168.2	400.7	276.0	269.6	243.6	32.2	1575.5	11.8
Soil depth	Deep		1597.2	952.5	1584.8	1776.0	1833.7	1857.5	242.2	9843.9	73.5
	Medium	C	120.8	28.0	30.2	27.5	20.8	9.4	3.6	240.3	1.8
	Shallow	CC	421.0	225.3	654.3	449.4	294.2	206.2	20.5	2270.7	16.9
Soil fertility	High		1264.6	632.0	742.0	601.0	598.9	310.5	20.3	4169.2	31.1
	Medium	C	182.9	133.7	314.3	611.4	809.8	827.7	125.4	3005.3	22.4
	Low	CC	691.4	440.1	1213.0	1040.5	740.0	934.8	120.6	5180.5	38.7
Soil drainage	Good		2104.7	1130.7	1967.2	1971.0	1863.7	1787.1	232.8	11057.2	82.5
	Poor	CC	34.2	75.1	302.1	281.9	285.0	285.9	33.5	1297.7	9.7
Soil texture	Medium/fine		1111.7	795.7	1596.7	1620.6	1597.0	1753.7	247.8	8723.2	65.1
	Sandy/stony	CC	307.6	135.0	244.7	179.5	124.6	73.5	5.9	1070.8	8.0
	Cracking clay	C	719.6	275.1	427.9	452.7	427.2	245.9	12.6	2561.0	19.1
Soil chemical constraints	None		1906.2	957.9	2102.3	2160.4	2092.6	2039.9	263.9	11523.3	86.0
	S/S/G*	CC	232.7	247.9	167.0	92.4	56.1	33.2	2.4	831.7	6.2
Miscellaneous land units		CC	613.6	163.4	113.4	62.7	53.3	36.5	1.7	1044.5	7.8
Total without constraints			0	0	0	134.6	226.4	108.4	0	469.4	3.5
Total with moderate constraints		C	0	0	527.9	541.8	672.1	617.8	103.2	2462.8	18.4
Total with severe constraints		CC	2752.6	1369.2	1854.7	1639.2	1303.5	1383.4	164.7	10467.3	78.1
Total	(10 ⁶ ha)		2752570	1369.2	2382.7	2315.6	2202.0	2109.6	268.0	13399.5	100.0
	(%)		20.5	10.2	17.8	17.3	16.4	15.7	2.0	100.0	

* Salinity/Sodicity/Gypsum

C: Moderate or slight constraint

CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

5.2 Crop suitability

5.2.1 Rain-fed crops

A total of 24 crop species, four pasture types and one fodder crop, comprising together 154 crop/LUTs were assessed each at three defined levels of inputs and management. A full list of Land Utilization Types (LUTs) is shown in Table 8 at the beginning of Chapter 4. The results show, that for wheat some 6.9 percent of the total land area is suitable (VS+S+MS) for rain-fed cultivation at high level of inputs. In developed countries this is 12.8 percent and for developing countries only some 3 percent. For maize the situation is reversed. In developing countries 11.3 percent is assessed as suitable, while in developed countries the suitable area is only 3 percent. Globally, almost 1.1 thousand million ha (i.e., about 8 percent) is suitable for grain-maize. Results of crop suitability analysis have been summarized in tabular and map form. Tables 20 to 22 and Tables 23 to 25 present examples of results in terms of *gross*²⁴ extents of land with cultivation potential for rain-fed production of respectively wheat and grain maize under high, intermediate and low levels of inputs in 22 major world regions.

Plate 29 and 30 present suitability maps of rain-fed production at intermediate level of inputs for wheat and grain-maize. In these maps, the results for each 5 minute latitude/longitude grid-cell of the FAO DSMW are represented by a suitability index *SI*, which is reflecting the suitability make-up of a grid-cell in accordance with the definition of suitability classes in AEZ, namely as:

$$SI = VS*0.9 + S*0.7 + MS*0.5 + mS*0.3.$$

Plates 31 to 36 present rain-fed suitability maps at intermediate level of inputs of respectively cereals, roots and tubers, pulses, oil crops, sugar crops and cotton. The algorithm examines in each grid-cell all the crop types belonging to a particular crop group. Among these it determines the LUT that maximizes agronomic suitability. In Appendix I, Tables A23 to A28 and Tables A29 to A34, summarize *gross* extents of land with cultivation potential for the above crop groups under rain-fed conditions, by 22 major world regions, at respectively intermediate and high input levels.

For example, for rain-fed cereal food crops at intermediate input level, we estimate about 2.5 billion ha of gross extents of land to be potentially suitable (VS+S+MS). Of these, some 1.6 billion ha are assessed as very suitable or suitable (VS+S) for at least one cereal type. In other words, about 18.7 percent of the Earth's terrestrial surface is adjudged cultivation potential for cereal crops. As pointed out above, these estimates are termed 'gross' extents as they do not include specific allowances for other land uses. An interpretation of how much of these potentially suitable areas would actually be available for cereal production is more difficult to achieve. This will be discussed later on.

For other crop groups the estimates of gross extents with cultivation potential of respectively (VS+S+MS) and (VS+S) areas are as follows: roots and tubers 1.5 billion ha and 0.8 billion ha; pulses 1.5 billion ha and 0.7 billion ha; oil crops 2.0 billion ha and 1.1 billion ha; sugar crops 0.9 billion ha and 0.4 billion ha; and cotton 0.6 billion ha and 0.3 billion ha. The data tables in Appendix I, A23 to A34, show how the suitable extents are distributed over major world regions.

²⁴ The extents in these tabulations are termed 'gross' since we did not subtract land required for other uses, such as infrastructure and settlements, or legally protected areas. In reality, some 10% to 30% of potentially suitable areas may not be available for agriculture due to other competing uses.

Table 20 Gross extents with cultivation potential for rain-fed wheat (1000ha) – high input level

REGION	NAME	TOTAL ²⁵	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	52331	137648	83470	12.8	40671	14.7	1824378	85.3
21	Eastern Europe	170952	17473	42094	29381	52.0	22364	65.1	59640	34.9
22	Northern Europe	172524	3433	21550	13495	22.3	8758	27.4	125288	72.6
23	Southern Europe	131643	6391	8243	6001	15.7	2686	17.7	108322	82.3
24	Western Europe	109547	16781	20390	10157	43.2	7398	50.0	54821	50.0
25	Russian Federation	1674146	20758	54445	92570	10.0	50498	13.0	1455875	87.0
		2258812	64836	146722	151604	16.1	91704	20.1	1803946	79.9
31	Caribbean	23397	0	0	8	0.0	213	0.9	23176	99.1
32	Central America	248353	1362	2169	1823	2.2	1030	2.6	241969	97.4
		271750	1362	2169	1831	2.0	1243	2.4	265145	97.6
41	South America	1777573	25743	44235	40839	6.2	32686	8.1	1634070	91.9
51	Oceania	793540	4477	10139	12972	3.5	9692	4.7	756260	95.3
52	Polynesia	56118	0	0	0	0.0	186	0.3	55932	99.7
		849658	4477	10139	12972	3.2	9878	4.4	812192	95.6
61	Eastern Africa	639474	5829	12108	11701	4.6	7675	5.8	602161	94.2
62	Middle Africa	657061	164	988	2733	0.6	1971	0.9	651205	99.1
63	Northern Africa	794112	274	1590	2047	0.5	1336	0.7	788865	99.3
64	Southern Africa	266428	354	949	1120	0.9	583	1.1	263422	98.9
65	Western Africa	632996	0	33	39	0.0	16	0.0	632908	100.0
		2990071	6621	15668	17640	1.3	11581	1.7	2938561	98.3
71	Western Asia	432992	675	3435	6372	2.4	3371	3.2	419139	96.8
81	Southeast. Asia	444483	172	2653	4489	1.6	4131	2.6	433038	97.4
82	South Asia	671842	182	1646	4913	1.0	5134	1.8	659967	98.2
84	East Asia	1112296	2804	28441	31588	5.6	15690	7.1	1033773	92.9
85	Central Asia	414363	492	603	4205	1.3	2728	1.9	406335	98.1
86	Japan	37178	2111	2479	1855	17.3	819	19.5	29914	80.5
		2680162	5761	35822	47050	3.3	28502	4.4	2563027	95.6
	DEVELOPING	8171488	38051	98850	111877	3.0	76750	4.0	7845960	96.0
	DEVELOPED	5228028	123755	296988	249901	12.8	142886	15.6	4414498	84.4
	WORLD TOTAL	13399516	161806	395838	361778	6.9	219636	8.5	12260458	91.5

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

²⁵ Total extent derived from digital version of the Soil Map of the World (FAO, 1995c).

Table 21 Gross extents with cultivation potential for rain-fed wheat (1000ha) – intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	47600	133704	101895	13.2	77355	16.9	1777944	83.1
21	Eastern Europe	170952	22244	40029	35822	57.4	19662	68.9	53195	31.1
22	Northern Europe	172524	5385	13873	15049	19.9	10308	25.9	127909	74.1
23	Southern Europe	131643	7111	13171	15668	27.3	13130	37.3	82563	62.7
24	Western Europe	109547	19555	22273	14198	51.1	7672	58.1	45849	41.9
25	Russian Federation	1674146	20799	78123	74516	10.4	80400	15.2	1420308	84.8
		2258812	75094	167469	155253	17.6	131172	23.4	1729824	76.6
31	Caribbean	23397	0	0	6	0.0	225	1.0	23166	99.0
32	Central America	248353	1350	3144	4690	3.7	5317	5.8	233852	94.2
		271750	1350	3144	4696	3.4	5542	5.4	257018	94.6
41	South America	1777573	22693	43168	47497	6.4	43719	8.8	1620496	91.2
51	Oceania	793540	6374	13279	16484	4.6	17411	6.7	739992	93.3
52	Polynesia	56118	0	0	0	0.0	145	0.3	55973	99.7
		849658	6374	13279	16484	4.3	17556	6.3	795965	93.7
61	Eastern Africa	639474	5367	17900	20789	6.9	19160	9.9	576258	90.1
62	Middle Africa	657061	732	2206	4495	1.1	5594	2.0	644034	98.0
63	Northern Africa	794112	614	2836	5544	1.1	5796	1.9	779322	98.1
64	Southern Africa	266428	575	2975	5628	3.4	5832	5.6	251418	94.4
65	Western Africa	632996	0	26	49	0.0	4	0.0	632917	100.0
		2990071	7288	25943	36505	2.3	36386	3.5	2883949	96.5
71	Western Asia	432992	844	5286	12924	4.4	16346	8.2	397592	91.8
81	Southeast. Asia	444483	101	1803	4064	1.3	5056	2.5	433459	97.5
82	South Asia	671842	256	4722	7914	1.9	13031	3.9	645919	96.1
84	East Asia	1112296	2151	18804	31597	4.7	41963	8.5	1017781	91.5
85	Central Asia	414363	387	1339	6405	2.0	11815	4.8	394417	95.2
86	Japan	37178	1063	3277	3540	21.2	3182	29.8	26116	70.2
		2680162	3958	29945	53520	3.3	75047	6.1	2517692	93.9
	DEVELOPING	8171488	35070	104209	151602	3.6	174003	5.7	7706604	94.3
	DEVELOPED	5228028	130131	317729	277172	13.9	229120	18.3	4273876	81.7
	WORLD TOTAL	13399516	165201	421938	428774	7.6	403123	10.6	11980480	89.4

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Table 22 Gross extents with cultivation potential for rain-fed wheat (1000ha) – low input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	60770	112686	124511	13.9	109473	19.1	1731059	80.9
21	Eastern Europe	170952	28710	42177	33112	60.8	9197	66.2	57759	33.8
22	Northern Europe	172524	3159	13160	15739	18.6	8800	23.7	131664	76.3
23	Southern Europe	131643	9148	15839	16648	31.6	12760	41.3	77246	58.7
24	Western Europe	109547	19638	21832	9859	46.9	4981	51.4	53237	48.6
25	Russian Federation	1674146	13419	73623	100906	11.2	65140	15.1	1421061	84.9
		2258812	74074	166631	176264	18.5	100878	22.9	1740967	77.1
31	Caribbean	23397	0	0	2	0.0	191	0.8	23204	99.2
32	Central America	248353	1547	3794	5293	4.3	6662	7	231058	93.0
		271750	1547	3794	5295	3.9	6853	6.4	254262	93.6
41	South America	1777573	18134	37699	43776	5.6	45928	8.2	1632033	91.8
51	Oceania	793540	6270	14456	16584	4.7	19715	7.2	736516	92.8
52	Polynesia	56118	0	0	0	0.0	199	0.4	55918	99.6
		849658	6270	14456	16584	4.4	19914	6.7	792434	93.3
61	Eastern Africa	639474	3844	17258	25759	7.3	27332	11.6	565278	88.4
62	Middle Africa	657061	396	1966	5686	1.2	9336	2.6	639677	97.4
63	Northern Africa	794112	1166	4278	6291	1.5	5593	2.2	776784	97.8
64	Southern Africa	266428	1650	3639	5532	4.1	6667	6.6	248938	93.4
65	Western Africa	632996	0	0	2	0.0	39	0	632955	100.0
		2990071	7056	27141	43270	2.6	48967	4.2	2863632	95.8
71	Western Asia	432992	2312	8075	17245	6.4	13080	9.4	392281	90.6
81	Southeast. Asia	444483	0	115	1427	0.3	6080	1.7	436865	98.3
82	South Asia	671842	395	3507	9467	2.0	18260	4.7	640213	95.3
84	East Asia	1112296	3614	24195	36366	5.8	49504	10.2	998618	89.8
85	Central Asia	414363	882	1774	8429	2.7	21972	8	381308	92.0
86	Japan	37178	419	2647	4201	19.5	4105	30.6	25806	69.4
		2680162	5310	32238	59890	3.6	99921	7.4	2482810	92.6
	DEVELOPING	8171488	33940	106300	165275	3.7	210843	6.3	7655130	93.7
	DEVELOPED	5228028	141533	296420	321560	14.5	234171	19	4234348	81.0
	WORLD TOTAL	13399516	175473	402720	486835	7.9	445014	11.3	11889478	88.7

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Table 23 Gross extents with cultivation potential for rain-fed grain maize (1000ha) – high input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	20380	53051	29468	4.8	5979	5.1	2029620	94.9
21	Eastern Europe	170952	40	3380	1425	2.8	279	3.0	165828	97.0
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	643	1737	602	2.3	128	2.4	128533	97.6
24	Western Europe	109547	34	1805	910	2.5	118	2.6	106680	97.4
25	Russian Federation	1674146	0	3161	534	0.2	41	0.2	1670410	99.8
		2258812	717	10083	3471	0.6	566	0.7	2243975	99.3
31	Caribbean	23397	218	1393	1583	13.7	4397	32.4	15806	67.6
32	Central America	248353	4353	4650	5432	5.8	14787	11.8	219131	88.2
		271750	4571	6043	7015	6.5	19184	13.5	234937	86.5
41	South America	1777573	22219	76786	88849	10.6	182745	20.8	1406974	79.2
51	Oceania	793540	6460	14189	14896	4.5	6062	5.2	751933	94.8
52	Polynesia	56118	61	125	310	0.9	4654	9.2	50968	90.8
		849658	6521	14314	15206	4.2	10716	5.5	802901	94.5
61	Eastern Africa	639474	45758	62008	51930	25.0	36171	30.6	443607	69.4
62	Middle Africa	657061	30562	30649	38740	15.2	88715	28.7	468395	71.3
63	Northern Africa	794112	33542	16335	13668	8.0	8372	9.1	722195	90.9
64	Southern Africa	266428	250	1827	2183	1.6	2395	2.5	259773	97.5
65	Western Africa	632996	26731	38694	35718	16.0	39964	22.3	491889	77.7
		2990071	136843	149513	142239	14.3	175617	20.2	2385859	79.8
71	Western Asia	432992	0	0	0	0.0	0	0.0	432992	100.0
81	Southeast. Asia	444483	368	14520	22382	8.4	45180	18.5	362033	81.5
82	South Asia	671842	38479	77713	47724	24.4	22115	27.7	485811	72.3
84	East Asia	1112296	22030	33885	29043	7.6	14427	8.9	1012911	91.1
85	Central Asia	414363	57	78	140	0.1	143	0.1	413945	99.9
86	Japan	37178	1483	2009	1485	13.4	770	15.5	31431	84.5
		2680162	62417	128205	100774	10.9	82635	14.0	2306131	86.0
	DEVELOPING	8171488	224628	358663	337702	11.3	464065	16.9	6786430	83.1
	DEVELOPED	5228028	29040	79332	49320	3.0	13377	3.3	5056959	96.7
	WORLD TOTAL	13399516	253668	437995	387022	8.1	477442	11.6	11843389	88.4

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Table 24 Gross extents with cultivation potential for rain-fed grain maize (1000ha) – intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	7703	64953	97671	8.0	47489	10.2	1920682	89.8
21	Eastern Europe	170952	473	6797	17546	14.5	11764	21.4	134372	78.6
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	964	2414	3907	5.5	2918	7.8	121440	92.2
24	Western Europe	109547	33	1813	6632	7.7	4493	11.8	96576	88.2
25	Russian Federation	1674146	161	1046	13167	0.9	10451	1.5	1649321	98.5
		2258812	1631	12070	41252	2.4	29626	3.7	2174233	96.3
31	Caribbean	23397	165	932	1234	10.0	2938	22.5	18128	77.5
32	Central America	248353	2726	4893	6671	5.8	9488	9.6	224575	90.4
		271750	2891	5825	7905	6.1	12426	10.7	242703	89.3
41	South America	1777573	11462	64017	93019	9.5	103056	15.3	1506019	84.7
51	Oceania	793540	6137	11424	14728	4.1	19353	6.5	741898	93.5
52	Polynesia	56118	48	134	236	0.7	532	1.7	55168	98.3
		849658	6185	11558	14964	3.8	19885	6.2	797066	93.8
61	Eastern Africa	639474	25876	58708	64929	23.4	48920	31.0	441041	69.0
62	Middle Africa	657061	10855	22754	38137	10.9	49902	18.5	535413	81.5
63	Northern Africa	794112	13561	15685	12670	5.3	13990	7.0	738206	93.0
64	Southern Africa	266428	414	3148	5777	3.5	9070	6.9	248019	93.1
65	Western Africa	632996	7292	40844	36548	13.4	33740	18.7	514572	81.3
		2990071	57998	141139	158061	11.9	155622	17.2	2477251	82.8
71	Western Asia	432992	402	271	560	0.3	516	0.4	431243	99.6
81	Southeast. Asia	444483	224	3377	11555	3.4	18687	7.6	410640	92.4
82	South Asia	671842	23185	58039	41812	18.3	31632	23.0	517174	77.0
84	East Asia	1112296	4717	17721	26779	4.4	29469	7.1	1033610	92.9
85	Central Asia	414363	174	398	1079	0.4	3069	1.1	409643	98.9
86	Japan	37178	489	1809	2374	12.6	2343	18.9	30163	81.1
		2680162	28789	81344	83599	7.2	85200	10.4	2401230	89.6
	DEVELOPING	8171488	101101	290921	341006	9.0	355009	13.3	7083451	86.7
	DEVELOPED	5228028	15960	90256	156025	5.0	98811	6.9	4866976	93.1
	WORLD TOTAL	13399516	117061	381177	497031	7.4	453820	10.8	11950427	89.2

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Table 25 Gross extents with cultivation potential for rain-fed grain maize (1000ha) – low input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	18822	75827	94673	8.9	51424	11.3	1897753	88.7
21	Eastern Europe	170952	694	11335	22397	20.1	21022	32.4	115504	67.6
22	Northern Europe	172524	0	0	0	0.0	5	0.0	172520	100.0
23	Southern Europe	131643	979	2132	4950	6.1	3114	8.5	120468	91.5
24	Western Europe	109547	22	513	7878	7.7	10387	17.2	90750	82.8
25	Russian Federation	1674146	241	12055	22805	2.1	19790	3.3	1619259	96.7
		2258812	1936	26035	58030	3.8	54318	6.2	2118501	93.8
31	Caribbean	23397	209	1121	2820	17.7	3029	30.7	16216	69.3
32	Central America	248353	2070	4170	9570	6.4	12948	11.6	219596	88.4
		271750	2279	5291	12390	7.3	15977	13.2	235812	86.8
41	South America	1777573	10710	62598	103040	9.9	249851	24.0	1351374	76.0
51	Oceania	793540	2694	8262	14295	3.2	17343	5.4	750946	94.6
52	Polynesia	56118	13	85	246	0.6	979	2.4	54796	97.6
		849658	2707	8347	14541	3.0	18322	5.2	805742	94.8
61	Eastern Africa	639474	18588	55718	65820	21.9	60338	31.3	439009	68.7
62	Middle Africa	657061	3899	23166	41987	10.5	93674	24.8	494337	75.2
63	Northern Africa	794112	4383	16817	17033	4.8	10845	6.2	745033	93.8
64	Southern Africa	266428	347	2760	5179	3.1	7782	6.0	250361	94.0
65	Western Africa	632996	3152	30807	43490	12.2	54044	20.8	501504	79.2
		2990071	30369	129268	173509	11.1	226683	18.7	2430244	81.3
71	Western Asia	432992	330	201	476	0.2	407	0.3	431577	99.7
81	Southeast. Asia	444483	118	2733	13576	3.7	24256	9.2	403803	90.8
82	South Asia	671842	12752	37209	50044	14.9	45063	21.6	526771	78.4
84	East Asia	1112296	6871	18681	26915	4.7	32843	7.7	1026986	92.3
85	Central Asia	414363	25	248	722	0.2	1579	0.6	411789	99.4
86	Japan	37178	188	781	2513	9.4	2846	17.0	30850	83.0
		2680162	19954	59652	93770	6.5	106587	10.4	2400199	89.6
	DEVELOPING	8171488	63467	256314	380918	8.6	597638	15.9	6873152	84.1
	DEVELOPED	5228028	23640	110905	169511	5.8	125931	8.2	4798050	91.8
	WORLD TOTAL	13399516	87107	367219	550429	7.5	723569	12.9	11671202	87.1

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

5.2.2 Rain-fed and/or irrigated crops

The Global AEZ model allows to assess potential crop suitability for the combination of rain-fed and irrigated crop cultivation. The results have been used to highlight regions where the availability of irrigation facilities would result in substantial increases of potential production and areas with cultivation potential. For the assessment of irrigated land productivity potentials, it has been assumed that (i) water resources of good quality are available, and (ii) irrigation infrastructure is in place. In other words, the assessment identifies areas where climate, soils and terrain permit irrigated crop cultivation but does not undertake a quantification of water availability within a watershed. However, suitability in hyper-arid (LGP = 0 days) and arid regions (LGP < 60 days) was limited to specific soil conditions, such as Fluvisols and Gleysols in flat terrain conditions.

Table 26 shows the estimated percentage of the Earth's terrestrial surface that is considered suitable for the six crop groups, under respectively rain-fed conditions and for rain-fed plus irrigation conditions. For intermediate level of inputs the estimates include very suitable, suitable and moderately suitable areas (VS+S+MS). At high level of input, very suitable and suitable extents (VS+S) are accounted for. The results for intermediate level of inputs indicate that irrigation could increase the extents of land with cultivation potential for staple food crops (cereals, roots and tubers, pulses, oil crops) by some 6 to 11 percent. Larger relative improvements from irrigation would result for sugar crops (about 35 %) and cotton (about 20 %). The potential contribution from irrigation becomes more pronounced when looking at the prime suitability classes, i.e., VS and S, as is done for high level of inputs. For the four staple food crop groups the increases in VS+S extents range from 13 to 31 percent, for sugar crops the respective area nearly doubles (about 93%), and for cotton 46 percent more land is assessed as very suitable or suitable.

Table 26 Percentage of global land surface potentially suitable for crop production

	Rain-fed cultivation potential		Rain-fed and/or irrigated cultivation potential	
	High input (% VS+S)	Intermediate input (% VS+S+MS)	High input (% VS+S)	Intermediate input (% VS+S+MS)
Cereals	14.9	18.7	16.8	19.8
Roots & Tubers	8.5	11.3	10.9	12.6
Pulses	7.8	11.2	10.1	12.2
Oil crops	11.2	15.2	14.6	16.5
Sugar crops	4.0	6.7	7.7	9.1
Cotton	3.3	4.3	4.8	5.2

The extents with cultivation potential for rain-fed and/or irrigated wheat, grain-maize and wetland rice at high and intermediate levels of input are given in Tables 27 to 32, respectively. Plates 37, 38 and 39 present, for the same crops under rain-fed and/or irrigated conditions, suitability maps at high input level. The results for wheat and grain-maize suggest gains of quite comparable magnitude. For both crops about 1 billion ha, i.e. about 7.5 percent of the global land surface, are assessed as very suitable, suitable or moderately suitable at intermediate levels of inputs. Extents very suitable and suitable (VS+S) under rain-fed conditions are larger for grain-maize than for wheat. For both crops, consideration of irrigation increases the extents of VS+S land by just over 40 percent, whereas the VS+S+MS areas increase only by about 12 percent. In other words, the results suggest that irrigation is more important in providing stable water supply in areas of climatic variability rather than for bringing land in hyper-arid and arid regions into cultivation. For wheat the VS+S estimates under rain-fed and rain-fed plus irrigated conditions are respectively 558 and 804 million ha; for grain-maize we obtained 692 and 975 million ha.

Table 27 Gross extents with cultivation potential for rain-fed and/or irrigated wheat (1000 ha) – high input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	100067	128872	72821	14.1	37161	15.8	1799577	84.2
21	Eastern Europe	170952	27247	38780	26327	54.0	20219	65.9	58379	34.1
22	Northern Europe	172524	6196	18974	13309	22.3	8758	27.4	125287	72.6
23	Southern Europe	131643	9703	7723	4781	16.9	2387	18.7	107049	81.3
24	Western Europe	109547	22357	16963	8670	43.8	7353	50.5	54204	49.5
25	Russian Federation	1674146	37331	74496	79540	11.4	44913	14.1	1437866	85.9
		2258812	102834	156936	132627	17.4	83630	21.1	1782785	78.9
31	Caribbean	23397	0	0	8	0.0	213	0.9	23176	99.1
32	Central America	248353	1528	3556	2011	2.9	1026	3.3	240232	96.7
		271750	1528	3556	2019	2.6	1239	3.1	263408	96.9
41	South America	1777573	36391	48334	39119	7.0	31547	8.7	1622182	91.3
51	Oceania	793540	20243	23584	13043	7.2	8094	8.2	728576	91.8
52	Polynesia	56118	0	0	0	0.0	186	0.3	55932	99.7
		849658	20243	23584	13043	6.7	8280	7.7	784508	92.3
61	Eastern Africa	639474	7729	22084	16253	7.2	7649	8.4	585759	91.6
62	Middle Africa	657061	1130	4714	4819	1.6	1971	1.9	644427	98.1
63	Northern Africa	794112	3801	12412	3957	2.5	1197	2.7	772745	97.3
64	Southern Africa	266428	1204	5767	2157	3.4	572	3.6	256728	96.4
65	Western Africa	632996	409	2050	264	0.4	16	0.4	630257	99.6
		2990071	14273	47027	27450	3.0	11405	3.3	2889916	96.7
71	Western Asia	432992	3160	7003	6255	3.8	3114	4.5	413460	95.5
81	Southeast. Asia	444483	174	3028	4671	1.8	4128	2.7	432482	97.3
82	South Asia	671842	824	30932	15201	7.0	4782	7.7	620103	92.3
84	East Asia	1112296	9375	47163	37153	8.4	15540	9.8	1003065	90.2
85	Central Asia	414363	6463	7325	5152	4.6	2436	5.2	392987	94.8
86	Japan	37178	2111	2479	1855	17.3	819	19.5	29914	80.5
		2680162	18947	90927	64032	6.5	27705	7.5	2478551	92.5
	DEVELOPING	8171488	72188	194368	137020	4.9	74377	5.8	7693535	94.2
	DEVELOPED	5228028	225255	311871	220346	14.5	129704	17.0	4340852	83.0
	WORLD TOTAL	13399516	297443	506239	357366	8.7	204081	10.2	12034387	89.8

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Table 28 Gross extents with cultivation potential for rain-fed and/or irrigated wheat (1000 ha) – intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	61151	137905	96644	13.8	69768	17.1	1773030	82.9
21	Eastern Europe	170952	25400	40653	34243	58.7	17948	69.2	52708	30.8
22	Northern Europe	172524	5814	13567	14937	19.9	10297	25.9	127909	74.1
23	Southern Europe	131643	9106	12977	14917	28.1	12550	37.6	82093	62.4
24	Western Europe	109547	20916	21858	13422	51.3	7589	58.2	45762	41.8
25	Russian Federation	1674146	29864	88777	69468	11.2	67624	15.3	1418413	84.7
		2258812	91100	177832	146987	18.4	116008	23.5	1726885	76.5
31	Caribbean	23397	0	0	6	0.0	225	1.0	23166	99.0
32	Central America	248353	1466	3862	4775	4.1	5126	6.1	233124	93.9
		271750	1466	3862	4781	3.7	5351	5.7	256290	94.3
41	South America	1777573	29689	43534	46412	6.7	42861	9.1	1615077	90.9
51	Oceania	793540	17938	24076	16460	7.4	12951	9.0	722115	91.0
52	Polynesia	56118	0	0	0	0.0	145	0.3	55973	99.7
		849658	17938	24076	16460	6.9	13096	8.4	778088	91.6
61	Eastern Africa	639474	5893	20659	22956	7.7	18731	10.7	571235	89.3
62	Middle Africa	657061	761	2826	5006	1.3	5573	2.2	642895	97.8
63	Northern Africa	794112	2417	8082	6278	2.1	5278	2.8	772057	97.2
64	Southern Africa	266428	769	3880	6199	4.1	5596	6.2	249984	93.8
65	Western Africa	632996	194	863	337	0.2	4	0.2	631598	99.8
		2990071	10034	36310	40776	2.9	35182	4.1	2867769	95.9
71	Western Asia	432992	2416	7321	12757	5.2	15608	8.8	394890	91.2
81	Southeast. Asia	444483	101	1852	4075	1.4	5037	2.5	433418	97.5
82	South Asia	671842	532	19466	16905	5.5	11454	7.2	623485	92.8
84	East Asia	1112296	4888	25166	32974	5.7	41024	9.4	1008244	90.6
85	Central Asia	414363	1721	5391	6511	3.3	8708	5.4	392032	94.6
86	Japan	37178	1063	3277	3544	21.2	3177	29.8	26117	70.2
		2680162	8305	55152	64009	4.8	69400	7.3	2483296	92.7
	DEVELOPING	8171488	50847	142902	165191	4.4	165370	6.4	7647178	93.6
	DEVELOPED	5228028	171252	343090	263635	14.9	201904	18.7	4248147	81.3
	WORLD TOTAL	13399516	222099	485992	428826	8.5	367274	11.2	11895325	88.8

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Table 29 Gross extents with cultivation potential for rain-fed and/or irrigated grain maize (1000 ha) – high input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	64649	69840	32994	7.8	5835	8.1	1965180	91.9
21	Eastern Europe	170952	1536	8789	4174	8.5	279	8.6	156174	91.4
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	3549	5567	1448	8.0	128	8.1	120951	91.9
24	Western Europe	109547	258	3707	1813	5.3	118	5.4	103651	94.6
25	Russian Federation	1674146	1901	8634	3508	0.8	41	0.8	1660062	99.2
		2258812	7244	26697	10943	2.0	566	2.0	2213362	98.0
31	Caribbean	23397	303	1320	1583	13.7	4397	32.5	15794	67.5
32	Central America	248353	6145	5977	5424	7.1	14496	12.9	216311	87.1
		271750	6448	7297	7007	7.6	18893	14.6	232105	85.4
41	South America	1777573	49196	79763	81547	11.8	179889	22.0	1387178	78.0
51	Oceania	793540	35944	25688	12995	9.4	5313	10.1	713600	89.9
52	Polynesia	56118	61	125	310	0.9	4654	9.2	50968	90.8
		849658	36005	25813	13305	8.8	9967	10.0	764568	90.0
61	Eastern Africa	639474	57952	66747	50899	27.5	34938	32.9	428938	67.1
62	Middle Africa	657061	33144	31324	37025	15.4	88254	28.9	467314	71.1
63	Northern Africa	794112	52980	21476	11687	10.8	7841	11.8	700128	88.2
64	Southern Africa	266428	5468	2415	1872	3.7	2374	4.6	254299	95.4
65	Western Africa	632996	33267	42409	34241	17.4	39038	23.5	484041	76.5
		2990071	182811	164371	135724	16.2	172445	21.9	2334720	78.1
71	Western Asia	432992	7068	3645	521	2.6	0	2.6	421758	97.4
81	Southeast. Asia	444483	370	14593	22496	8.4	45001	18.6	362023	81.4
82	South Asia	671842	53676	83930	40740	26.5	20820	29.6	472676	70.4
84	East Asia	1112296	32837	42849	28701	9.4	13700	10.6	994209	89.4
85	Central Asia	414363	6059	6547	1599	3.4	143	3.5	400015	96.5
86	Japan	37178	1483	2009	1485	13.4	770	15.5	31431	84.5
		2680162	94425	149928	95021	12.7	80434	15.7	2260354	84.3
	DEVELOPING	8171488	338526	403120	318645	13.0	455545	18.6	6655652	81.4
	DEVELOPED	5228028	109320	124234	58417	5.6	12484	5.8	4923573	94.2
	WORLD TOTAL	13399516	447846	527354	377062	10.1	468029	13.6	11579225	86.4

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Table 30 Gross extents with cultivation potential for rain-fed and/or irrigated grain maize (1000 ha) – intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	24283	70870	88488	8.6	44706	10.7	1910151	89.3
21	Eastern Europe	170952	1044	8762	18374	16.5	11659	23.3	131113	76.7
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	2995	4470	3836	8.6	2773	10.7	117569	89.3
24	Western Europe	109547	166	2646	7063	9.0	4447	13.1	95225	86.9
25	Russian Federation	1674146	689	4521	15338	1.2	10198	1.8	1643400	98.2
		2258812	4894	20399	44611	3.1	29077	4.4	2159831	95.6
31	Caribbean	23397	168	942	1233	10.0	2927	22.5	18127	77.5
32	Central America	248353	3667	5453	6692	6.4	9263	10.1	223278	89.9
		271750	3835	6395	7925	6.7	12190	11.2	241405	88.8
41	South America	1777573	28072	67946	85370	10.2	99031	15.8	1497154	84.2
51	Oceania	793540	26613	24134	14372	8.2	9079	9.4	719342	90.6
52	Polynesia	56118	48	134	237	0.7	532	1.7	55167	98.3
		849658	26661	24268	14609	7.7	9611	8.8	774509	91.2
61	Eastern Africa	639474	30525	62919	64143	24.6	46997	32.0	434890	68.0
62	Middle Africa	657061	11383	24184	37665	11.1	48828	18.6	535001	81.4
63	Northern Africa	794112	22141	18009	11772	6.5	12643	8.1	729547	91.9
64	Southern Africa	266428	1289	3739	5535	4.0	8639	7.2	247226	92.8
65	Western Africa	632996	9143	42698	35998	13.9	32553	19.0	512604	81.0
		2990071	74481	151549	155113	12.7	149660	17.8	2459268	82.2
71	Western Asia	432992	4080	2331	841	1.7	310	1.7	425430	98.3
81	Southeast. Asia	444483	226	3417	11649	3.4	18559	7.6	410632	92.4
82	South Asia	671842	31145	64137	39388	20.0	25107	23.8	512065	76.2
84	East Asia	1112296	9053	20434	26363	5.0	28569	7.6	1027877	92.4
85	Central Asia	414363	1944	2641	1714	1.5	2091	2.0	405973	98.0
86	Japan	37178	489	1837	2410	12.7	2308	18.9	30134	81.1
		2680162	42857	92466	81524	8.1	76634	11.0	2386681	89.0
	DEVELOPING	8171488	152884	318984	328600	9.8	336049	13.9	7034971	86.1
	DEVELOPED	5228028	56279	117240	149881	6.2	85170	7.8	4819458	92.2
	WORLD TOTAL	13399516	209163	436224	478481	8.4	421219	11.5	11854429	88.5

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Table 31 Gross extents with cultivation potential for rain-fed and/or irrigated wetland rice (1000 ha) – high input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	49213	36349	13253	4.6	4025	4.8	2035658	95.2
21	Eastern Europe	170952	2447	2335	1110	3.4	0	3.4	165060	96.6
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	5549	2401	347	6.3	31	6.3	123315	93.7
24	Western Europe	109547	487	235	12	0.7	0	0.7	108813	99.3
25	Russian Federation	1674146	1390	3681	2794	0.5	519	0.5	1665762	99.5
		2258812	9873	8652	4263	1.0	550	1.0	2235474	99.0
31	Caribbean	23397	2492	2442	869	24.8	264	25.9	17330	74.1
32	Central America	248353	6121	11241	6578	9.6	1695	10.3	222718	89.7
		271750	8613	13683	7447	10.9	1959	11.7	240048	88.3
41	South America	1777573	100709	165906	152004	23.6	110693	29.8	1248261	70.2
51	Oceania	793540	21014	28150	11408	7.6	1160	7.8	731808	92.2
52	Polynesia	56118	784	1370	2504	8.3	4364	16.1	47096	83.9
		849658	21798	29520	13912	7.7	5524	8.3	778904	91.7
61	Eastern Africa	639474	25422	24580	16267	10.4	13416	12.5	559789	87.5
62	Middle Africa	657061	22105	55684	63054	21.4	29923	26.0	486295	74.0
63	Northern Africa	794112	17704	26423	10946	6.9	5863	7.7	733176	92.3
64	Southern Africa	266428	5265	1287	75	2.5	11	2.5	259790	97.5
65	Western Africa	632996	11425	27987	23430	9.9	13619	12.1	556535	87.9
		2990071	81921	135961	113772	11.1	62832	13.2	2595585	86.8
71	Western Asia	432992	6715	2596	119	2.2	0	2.2	423562	97.8
81	Southeast. Asia	444483	17974	33851	23284	16.9	18775	21.1	350599	78.9
82	South Asia	671842	18575	54136	21681	14.0	10133	15.6	567317	84.4
84	East Asia	1112296	20625	25594	13242	5.3	2162	5.5	1050673	94.5
85	Central Asia	414363	4919	3405	470	2.1	16	2.1	405553	97.9
86	Japan	37178	1104	1404	382	7.8	89	8.0	34199	92.0
		2680162	63197	118390	59059	9.0	31175	10.1	2408341	89.9
	DEVELOPING	8171488	260835	436502	334523	12.6	210934	15.2	6928694	84.8
	DEVELOPED	5228028	81204	74555	29306	3.5	5824	3.7	5037139	96.3
	WORLD TOTAL	13399516	342039	511057	363829	9.1	216758	10.7	11965833	89.3

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Table 32 Gross extents with cultivation potential for rain-fed and/or irrigated wetland rice (1000 ha) – intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	34066	28807	20725	3.9	8535	4.3	2046365	95.7
21	Eastern Europe	170952	1296	2246	1399	2.9	103	3.0	165908	97.0
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	4016	2560	623	5.5	378	5.8	124066	94.2
24	Western Europe	109547	390	224	35	0.6	22	0.6	108876	99.4
25	Russian Federation	1674146	589	2970	3170	0.4	1183	0.5	1666234	99.5
		2258812	6291	8000	5227	0.9	1686	0.9	2237608	99.1
31	Caribbean	23397	1486	2506	1223	22.3	540	24.6	17642	75.4
32	Central America	248353	4239	9450	7547	8.6	3667	10.0	223450	90.0
		271750	5725	11956	8770	9.7	4207	11.3	241092	88.7
41	South America	1777573	54547	155415	146042	20.0	106592	26.0	1314977	74.0
51	Oceania	793540	13887	29848	15627	7.5	2172	7.8	732006	92.2
52	Polynesia	56118	53	1139	615	3.2	2884	8.4	51427	91.6
		849658	13940	30987	16242	7.2	5056	7.8	783433	92.2
61	Eastern Africa	639474	15848	19264	22173	9.0	23015	12.6	559174	87.4
62	Middle Africa	657061	10475	41309	58018	16.7	29627	21.2	517632	78.8
63	Northern Africa	794112	8969	14165	14035	4.7	6732	5.5	750211	94.5
64	Southern Africa	266428	2793	1275	352	1.7	22	1.7	261986	98.3
65	Western Africa	632996	5565	24866	28277	9.3	20862	12.6	553426	87.4
		2990071	43650	100879	122855	8.9	80258	11.6	2642429	88.4
71	Western Asia	432992	3570	1695	312	1.3	32	1.3	427383	98.7
81	Southeast. Asia	444483	5616	22563	25617	12.1	17596	16.1	373091	83.9
82	South Asia	671842	7852	41195	29124	11.6	15871	14.0	577800	86.0
84	East Asia	1112296	11245	24818	18378	4.9	5608	5.4	1052247	94.6
85	Central Asia	414363	2308	1687	740	1.1	102	1.2	409526	98.8
86	Japan	37178	567	1653	854	8.3	159	8.7	33945	91.3
		2680162	27588	91916	74713	7.2	39336	8.7	2446609	91.3
	DEVELOPING	8171488	134566	361347	352453	10.4	233150	13.2	7089972	86.8
	DEVELOPED	5228028	54811	68308	42433	3.2	12552	3.4	5049924	96.6
	WORLD TOTAL	13399516	189377	429655	394886	7.6	245702	9.4	12139896	90.6

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

Areas suitable for major crop groups are displayed in Appendix XV where Plates 40 to 45 present suitability maps for high level of inputs of respectively cereals, roots and tubers, pulses, oil crops, cotton, and sugar crops. Regional results are provided in Tables A35 to A40 and Tables A41 to A46 in Appendix I, which summarize gross extents of land with cultivation potential for these crop groups at respectively intermediate and high input levels.

5.2.3 Hyper-arid and arid land with cultivation potential under irrigation

Globally, some 3.6 billion hectares, i.e., about 27 percent of the Earth's land surface, are too dry for rain-fed agriculture (see Table 18 at beginning of this Chapter). As working hypothesis we have only considered for irrigation those soils in hyper-arid (LGP = 0 days) and arid (LGP < 60 days) zones that indicate possible availability of surface or groundwater resources. These soils are Fluvisols, which by definition are regularly flooded, and Gleysols, which indicate regular occurrence of high groundwater tables.

Table 33 Gross extents of potentially irrigable land in hyper-arid and arid zones very suitable and suitable (VS+S) for cereals

Region	Irrigated land in 1994-96 (1000 ha)	(A): Total VS+S rainfed & irrigated potential (1000 ha)	Hyper-arid zone (LGP = 0 days) VS+S irrigable land (high input)		Arid zone (LGP = 1-60 days) VS+S irrigable land (high input)		Hyper-arid and arid zones total VS+S irrigable land (high input)	
			(1000 ha)	% of (A)	(1000 ha)	% of (A)	(1000 ha)	% of (A)
North America	22120	256624	1152	0.4	1293	0.5	2445	1.0
Eastern Europe	7444	70075	0	0.0	0	0.0	0	0.0
Northern Europe	913	28100	0	0.0	0	0.0	0	0.0
Southern Europe	8742	18101	0	0.0	0	0.0	0	0.0
Western Europe	2686	39925	0	0.0	0	0.0	0	0.0
Russian Federation	5209	126075	0	0.0	1553	1.2	1553	1.2
	24994	282276	0	0.0	1553	0.6	1553	0.6
Caribbean	1359	7853	0	0.0	0	0.0	0	0.0
Central America	6668	32190	623	1.9	565	1.8	1188	3.7
	8027	40043	623	1.6	565	1.4	1188	3.0
South America	9785	540013	3936	0.7	1372	0.3	5308	1.0
Oceania	2788	91284	0	0.0	0	0.0	0	0.0
Polynesia	3	3398	0	0.0	0	0.0	0	0.0
	2791	94682	0	0.0	0	0.0	0	0.0
Eastern Africa	2073	169740	2327	1.4	2497	1.5	4824	2.8
Middle Africa	141	221798	159	0.1	117	0.1	276	0.1
Northern Africa	7866	92650	15087	16.3	1746	1.9	16833	18.2
Southern Africa	1349	11575	194	1.7	715	6.2	909	7.9
Western Africa	773	143867	3530	2.5	1907	1.3	5437	3.8
	12203	639630	21297	3.3	6982	1.1	28279	4.4
Western Asia	11506	15062	6315	41.9	703	4.7	7018	46.6
Southeast. Asia	15286	88588	0	0.0	0	0.0	0	0.0
South Asia	85667	177531	3582	2.0	1580	0.9	5162	2.9
East Asia	52814	99422	4450	4.5	652	0.7	5102	5.1
Central Asia	12142	16417	0	0.0	8494	51.7	8494	51.7
Japan	2744	5286	0	0.0	0	0.0	0	0.0
	168653	387244	8032	2.1	10726	2.8	18758	4.8
DEVELOPING	207432	1620104	40203	2.5	20348	1.3	60551	3.7
DEVELOPED	47437	635470	1152	0.2	2846	0.4	3998	0.6
WORLD TOTAL	254869	2255574	41355	1.8	23194	1.0	64549	2.9

Assuming availability of water resources, nearly 65 million hectares, i.e., only about 1.8 percent of these dry zones, were assessed as potentially very suitable and suitable (VS+S) for

cereal crops under irrigation. About 40 percent of this land, potentially suitable under irrigation, is located throughout Africa. Table 33 presents by major world region the estimated extents of irrigable land in hyper-arid (with a moisture growing period of zero days, LGP 0) and arid (with a moisture growing period of less than sixty days, LGP 1-59) zones potentially very suitable and suitable for cultivation of cereal crops. In comparison, FAO reports that about 255 million ha were irrigated globally in 1994-96. Note, however, that these irrigated lands were distributed among various climatic zones, not only hyper-arid and arid regions.

5.3 Crop yields

Maximum²⁶ agro-climatically attainable yield ranges were calculated for respectively tropics, sub-tropics and temperate/boreal zones. Table 34 presents potential yields for irrigated production at high and intermediate levels of inputs. Table 35 lists yield ranges for rain-fed conditions at high, intermediate and low levels of inputs. The maximum attainable yields for rain-fed conditions represent averages of simulated year-by-year yields attainable during the period 1960 to 1996. The yields are presented in ranges indicating the maximum attainable yields of the least and most productive cultivars for each of the 24 crop species in respectively tropics, subtropics and temperate/boreal zones.

With balanced fertilizer applications and proper pest and disease management (which is best possible at high level of inputs), only limited fallow will be required to maintain soil fertility and to keep pest and disease outbreaks in check. At low level of inputs, assuming virtually no application of chemical and only limited organic fertilizer, and very limited or no application of biocides, there is need for considerable fallow periods in the crop rotations to restore soil nutrient status and to break pest and disease cycles (see Appendix XII). The expected long-term yields as estimated by the Global AEZ procedures assume that proper crop/fallow cycles are respected. The yields attained on the long-term are well below the estimated maximum attainable yields when accounting for fallow period requirements.

Table 36 compares maximum attainable yields and long-term sustainable yields for the best crop among wheat, rice and grain-maize, averaged over all very suitable, suitable and moderately suitable land (VS+S+MS). The calculations assume the best suitable cereal to be chosen and aggregates yields for different major world regions and levels of inputs (see Section 4.4.4 for a discussion of fallow period requirements and cultivation factors in Global AEZ). On average, long-term sustainable yields are 10, 20, and 55 percent lower than maximum attainable yields, respectively at high, intermediate and low levels of inputs.

²⁶ To obtain representative results for a global study, the 99-percentile of non-zero yields (i.e., the yield level equalled or exceeded by just one percent of yields) over all grid-cells in the respective climatic zones has been chosen to represent maximum attainable yield potentials.

Table 34 Maximum attainable crop yield ranges (t/ha) for high and intermediate level inputs in tropical, subtropical and temperate environments under irrigated conditions

Crop	High Input Yields (t/ha)			Intermediate Input Yields (t/ha)		
	Tropics	Subtropics	Temperate	Tropics	Subtropics	Temperate
Wheat (hibernating)	n.a.	6.6 – 14.2	7.4 – 13.5	n.a.	4.6 – 10.2	5.2 – 9.7
Wheat (non-hibernating)	5.3 – 11.1	5.4 – 9.9	5.3 – 8.5	3.3 – 7.4	3.4 – 6.9	3.3 – 5.7
Rice (wetland)	7.9 – 12.2	8.7 – 12.7	8.2 – 10.9	6.1 – 9.5	6.5 – 9.9	6.3 – 8.7
Rice (dryland)	4.8 – 6.8	n.a.	n.a.	3.1 – 4.6	n.a.	n.a.
Maize (grain)	6.0 – 15.6	8.5 – 17.1	8.0 – 15.7	3.5 – 10.5	5.3 – 12.2	4.9 – 11.3
Maize (silage)	n.a.	17.0 – 26.0	15.9 – 24.0	n.a.	13.0 – 20.9	12.1 – 19.2
Barley (hibernating)	n.a.	6.6 – 14.2	7.4 – 13.5	n.a.	4.6 – 10.2	5.2 – 9.7
Barley (non-hibernating)	4.7 – 9.9	5.2 – 9.2	3.9 – 7.6	2.9 – 6.7	2.9 – 6.4	2.8 – 5.1
Sorghum	3.4 – 12.1	7.8 – 13.0	5.9 – 10.3	2.2 – 7.5	4.6 – 8.1	3.4 – 6.4
Pearl millet	4.2 – 5.8	n.a.	n.a.	2.5 – 3.7	n.a.	n.a.
Foxtail millet	n.a.	5.2 – 10.0	5.0 – 9.3	n.a.	3.6 – 7.2	3.5 – 6.7
Rye (hibernating)	n.a.	4.2 – 8.3	4.6 – 7.9	n.a.	2.9 – 5.9	3.3 – 5.7
Rye (non-hibernating)	n.a.	3.5 – 6.6	3.4 – 6.3	n.a.	2.1 – 4.1	2.0 – 3.9
White potato	7.4 – 15.8	8.1 – 16.5	7.8 – 15.2	4.9 – 10.6	5.4 – 11.1	5.2 – 10.2
Sweet potato	7.5 – 15.4	7.5 – 15.9	n.a.	5.0 – 10.6	5.0 – 10.9	n.a.
Cassava	16.6	n.a.	n.a.	11.0	n.a.	n.a.
Phaseolus bean	3.4 – 5.5	3.1 – 5.6	3.0 – 4.8	2.2 – 3.7	2.0 – 3.7	1.9 – 3.2
Chickpea	3.2 – 4.7	3.5 – 6.1	n.a.	2.0 – 3.1	2.2 – 4.1	n.a.
Cowpea	2.9 – 4.7	n.a.	n.a.	1.9 – 3.1	n.a.	n.a.
Soybean	3.1 – 4.8	4.6 – 5.5	4.3 – 5.1	2.0 – 3.2	3.0 – 3.6	2.8 – 3.4
Rape	4.5 – 5.6	4.5 – 6.0	4.7 – 5.7	2.6 – 3.5	2.9 – 3.8	2.8 – 3.6
Groundnut	3.1 – 4.7	3.2 – 4.9	3.1 – 4.6	2.0 – 3.1	2.0 – 3.3	2.0 – 3.0
Sunflower	5.6 – 6.7	4.9 – 6.1	4.7 – 5.8	3.9 – 4.8	3.4 – 4.4	3.3 – 4.1
Oil palm	8.7	6.4	n.a.	6.0	4.4	n.a.
Olive	n.a.	6.7	5.4	n.a.	4.1	3.3
Cotton	1.1 – 1.6	1.2 – 1.6	1.2 – 1.5	0.7 – 1.0	0.8 – 1.0	0.7 – 0.9
Sugarcane	21.0	20.1	n.a.	16.5	15.8	n.a.
Sugar beet	n.a.	7.1 – 9.3	6.7 – 8.6	n.a.	4.8 – 6.7	4.6 – 6.2
Banana/Plantain	11.5	11.5	n.a.	8.4	8.4	n.a.
Alfalfa	n.a.	26.7	21.5	n.a.	16.9	13.6

Table 35 Average of year 1960-1996 simulated maximum attainable crop yield ranges (t/ha) for high, intermediate and low level inputs in tropical, subtropical and temperate environments under rain-fed conditions

Crop	High Input Yields (t/ha)			Intermediate Input Yields (t/ha)			Low Input Yields (t/ha)		
	Tropics	Subtropics	Temperate	Tropics	Subtropics	Temperate	Tropics	Subtropics	Temperate
Wheat (hibernating)	n.a.	4.2 – 11.8	5.9 – 12.1	n.a.	2.9 - 8.4	4.1 - 8.7	n.a.	1.6 – 4.3	2.4 – 4.9
Wheat (non-hibernating)	4.5 – 8.5	4.6 – 8.0	4.6 – 7.7	2.8 – 5.7	2.9 – 5.4	2.9 – 5.2	1.2 – 2.7	1.3 – 3.0	1.5 – 2.7
Rice (wetland)	6.2 – 9.9	6.2 – 9.2	6.4 – 8.6	4.8 – 7.7	4.8 – 7.3	4.9 – 6.9	2.9 – 5.0	2.9 – 4.7	3.2 – 4.9
Rice (dryland)	3.5 – 5.5	n.a.	n.a.	2.3 – 3.7	n.a.	n.a.	1.2 – 1.9	n.a.	n.a.
Maize (grain)	4.6 – 12.5	6.3 – 12.3	6.1 – 12.1	2.7 – 8.5	4.0 – 8.9	3.8 – 8.7	1.1 – 5.1	1.8 – 5.8	1.8 – 5.3
Maize (silage)	n.a.	12.6 – 19.2	12.4 – 18.8	n.a.	9.7 – 15.2	9.4 – 15.1	n.a.	6.9 – 12.0	6.7 – 11.1
Barley (hibernating)	n.a.	4.2 – 11.8	5.9 – 12.1	n.a.	2.3 – 8.4	4.1 – 8.7	n.a.	1.6 – 4.3	2.4 – 4.9
Barley (non-hibernating)	4.1 – 7.7	3.0 – 7.3	3.5 – 6.8	2.5 – 5.2	2.2 – 5.1	2.5 – 4.6	1.1 – 2.7	1.1 – 2.8	1.3 – 2.5
Sorghum	2.6 – 9.7	5.8 – 8.7	3.6 – 6.3	1.7 – 6.1	3.4 – 5.5	2.1 – 3.9	0.9 – 2.6	1.5 – 2.4	0.9 – 2.0
Pearl millet	2.7 – 4.7	n.a.	n.a.	1.6 – 3.0	n.a.	n.a.	0.9 – 1.6	n.a.	n.a.
Foxtail millet	n.a.	3.7 – 7.0	4.1 – 6.8	n.a.	2.6 – 5.0	2.5 – 4.9	n.a.	1.5 – 2.8	1.4 – 2.7
Rye (hibernating)	n.a.	2.6 – 7.0	3.7 – 7.2	n.a.	1.9 – 5.0	2.6 – 5.2	n.a.	1.0 – 2.5	1.5 – 3.0
Rye (non-hibernating)	n.a.	2.8 – 5.9	3.0 – 5.7	n.a.	1.6 – 3.7	1.8 – 3.6	n.a.	0.6 – 1.4	0.8 – 1.6
White potato	5.8 – 11.8	5.4 – 11.6	6.4 – 10.3	3.8 – 8.0	3.6 – 7.8	4.3 – 6.9	2.1 – 4.0	1.9 – 4.1	2.3 – 3.7
Sweet potato	5.2 – 11.8	5.3 – 11.0	n.a.	3.5 – 8.1	3.5 – 7.6	n.a.	1.7 – 4.6	1.6 – 4.1	n.a.
Cassava	15.5	n.a.	n.a.	10.2	n.a.	n.a.	4.1	n.a.	n.a.
Phaseolus bean	2.8 – 4.2	2.4 – 4.0	2.5 – 3.7	1.8 – 2.8	1.5 – 2.6	1.6 – 2.4	0.9 – 1.3	0.8 – 1.2	0.8 – 1.2
Chickpea	1.9 – 3.1	1.9 – 2.9	n.a.	1.2 – 2.2	1.6 – 2.4	n.a.	0.6 – 1.0	0.8 – 1.0	n.a.
Cowpea	2.5 – 3.8	n.a.	n.a.	1.6 – 2.5	n.a.	n.a.	0.7 – 1.2	n.a.	n.a.
Soybean	2.7 – 3.8	3.4 - 4.2	3.4 – 3.8	1.7 – 2.5	2.2 – 2.8	2.2 – 2.6	0.8 – 1.2	1.0 – 1.2	0.9 – 1.1
Rape	3.7 – 4.4	2.6 – 4.5	3.9 – 4.4	2.2 – 2.8	1.6 – 2.8	2.3 – 3.0	0.9 – 1.3	0.7 – 1.1	1.0 – 1.3
Groundnut	2.7 – 3.8	2.6 - 3.5	1.8 – 2.6	1.7 – 2.5	1.7 – 2.4	1.1 – 1.9	0.8 - 1.2	0.8 – 1.2	0.5 – 0.9
Sunflower	4.1 – 4.9	3.4 – 4.0	3.7 – 3.9	2.9 – 3.5	2.3 – 2.9	2.6 – 2.7	1.6 – 2.1	1.4 – 1.7	1.5 – 1.6
Oil palm	7.5	3.7	n.a.	5.2	2.6	n.a.	2.8	1.5	n.a.
Olive	n.a.	5.9	4.6	n.a.	3.6	2.8	n.a.	1.7	1.2
Cotton	0.9 – 1.2	0.9 – 1.2	0.5 – 0.6	0.6 – 0.8	0.6 – 0.7	0.4 – 0.5	.16 - .28	.15 – .22	.12 – .16
Sugarcane	17.1	16.0	n.a.	13.4	12.6	n.a.	9.4	8.5	n.a.
Sugar beet	n.a.	5.0 – 6.3	5.4 – 6.0	n.a.	3.9 – 4.7	3.8 – 4.6	n.a.	2.2 – 3.6	2.3 – 2.7
Banana/Plantain	9.7	9.0	n.a.	6.8	6.6	n.a.	3.2	3.3	n.a.
Alfalfa	n.a.	23.8	19.9	n.a.	15.1	12.6	n.a.	7.4	6.2

Notes: The yields given in Tables 34 and 35 represent yields attained during the cultivation phase of cultivation-fallow cycles. In low and intermediate input agriculture, fallow and/or crop rotations are needed to maintain the soil nutrient balance and to break pest and disease cycles. The required intensity of fallow depends on crop rotations implemented, on soil characteristics such as soil nutrient availability and nutrient retention capacity, on climatic conditions and on management and agricultural inputs applied. As a rule of thumb for low level input/management conditions, fallow period requirements may vary between 30–90% of the cultivation-fallow cycle. For intermediate level input/management conditions, fallow requirements may vary between 10–30% (see also Table 36).

Table 36 Maximum attainable and long-term sustainable²⁷ yields for rain-fed wheat, rice, or grain-maize averaged over all VS+S+MS land, by region and level of inputs

Region	Low inputs		Intermediate inputs		High inputs	
	Short-term attainable (kg/ha)	Long-term sustainable (kg/ha)	Short-term attainable (kg/ha)	Long-term sustainable (kg/ha)	Short-term attainable (kg/ha)	Long-term sustainable (kg/ha)
North America	836	357	3558	2800	5784	5227
Eastern Europe	1142	407	4193	3326	6469	5862
Northern Europe	925	359	3732	2940	5795	5228
Southern Europe	927	338	3606	2844	6339	5715
Western Europe	1058	347	4335	3361	7031	6362
Russian Federation	739	348	2943	2467	4363	3966
Caribbean	1390	639	4091	3360	5884	5301
Central America	1076	534	3630	2999	5952	5378
South America	1154	595	3645	3009	5609	5079
Oceania	718	335	3187	2566	5334	4816
Polynesia	1360	843	3805	3263	5378	4968
Eastern Africa	1025	388	3822	3027	6914	6233
Middle Africa	1167	557	3765	3067	6197	5590
Northern Africa	1033	427	4145	3338	7506	6794
Southern Africa	812	396	3052	2513	4727	4278
Western Africa	984	406	3791	3020	6739	6086
Western Asia	843	370	3075	2525	4483	4074
Southeast. Asia	1341	696	3694	3080	5641	5120
South Asia	1093	474	4077	3274	6755	6087
East Asia	982	471	3386	2760	5837	5259
Central Asia	708	417	2957	2507	3646	3331
Japan	987	371	3844	3018	7259	6533
DEVELOPING	1089	511	3728	3033	6157	5564
DEVELOPED	869	358	3539	2825	5613	5079
WORLD TOTAL	998	448	3658	2955	5983	5409

5.4 Land with cultivation potential

Various ways are available for estimating the extent of land with cultivation potential for rain-fed crops. Any quantification depends on a variety of assumptions: the range of crop types considered, the definition of what minimum level of output qualifies as acceptable, the social acceptance of land-cover conversions (in particular forests), and the assumptions on what land constraints may be alleviated with modern inputs and investment. The results presented in this section are based on the following calculation procedures for each 5-minute grid-cell of the DSMW:

- (1) *Determine all land very suitable and suitable at high level of inputs for the crops offering the largest total extent;*
- (2) *Of the balance of land after (1), determine all land very suitable, suitable or moderately suitable at intermediate level of inputs for the crops offering the largest extent;*
- (3) *Of the balance of land after (1) and (2), determine all suitable land (i.e. very suitable, suitable, moderately suitable or marginally suitable) at low level of inputs for the crops offering the largest extent.*

²⁷ Long-term sustainable yields are calculated by applying a fallow period requirement factor dependent on climatic conditions, soil type, crop, and level of inputs/management (see Section 4.4.4).

The total extents obtained in this way for each grid-cell, referred to as *mixed* level of inputs, were calculated for rain-fed and rain-fed plus irrigated conditions. The results have been aggregated to various levels (e.g., climatic zones, country, and region).

Table 37 lists *gross* extents of land with cultivation potential for rain-fed conditions in comparison to levels of cultivated land use in 1994-96. Note that the extents in this table are termed 'gross' since no land was subtracted as is required for non-agricultural uses, such as infrastructure and settlements, nor legally protected areas. In reality, some 10 to 30 percent of gross suitable areas may not be available for cultivation even with full exploitation of suitable potentials for cropping.

Table 37 Extents of land in use for crop cultivation (1994-96)²⁸ and gross extents of land with potential for rain-fed cultivation (VS+S+MS)

REGION	TOTAL LAND (1000 ha)	Land in use for crop cultivation (FAOSTAT 1994-96)		VS+S+MS Land with rain-fed cultivation potential (mixed inputs)		Balance	
		(1000 ha)	(%)	(1000 ha)	(%)	(1000 ha)	(%)
North America	2138498	225278	10.5	405499	19.0	180221	8.4
Eastern Europe	170952	81716	47.8	125883	73.6	44167	25.8
Northern Europe	172524	21556	12.5	44572	25.8	23016	13.3
Southern Europe	131643	45632	34.7	59291	45.0	13659	10.4
Western Europe	109547	35143	32.1	66309	60.5	31166	28.5
Russian Federation	1674146	130055	7.8	238658	14.3	108603	6.5
Caribbean	23397	7601	32.5	11728	50.1	4127	17.6
Central America	248353	35937	14.5	57487	23.1	21550	8.7
South America	1777573	114787	6.5	925299	52.1	810512	45.6
Oceania	793540	51782	6.5	120652	15.2	68870	8.7
Polynesia	56118	1379	2.5	17860	31.8	16481	29.4
Eastern Africa	639474	45975	7.2	276735	43.3	230760	36.1
Middle Africa	657061	24772	3.8	364076	55.4	339304	51.6
Northern Africa	794112	44134	5.6	108814	13.7	64680	8.1
Southern Africa	266428	17437	6.5	34118	12.8	16681	6.3
Western Africa	632996	65384	10.3	195132	30.8	129748	20.5
Western Asia	432992	46075	10.6	36441	8.4	-9634	-2.2
Southeast. Asia	444483	89578	20.2	167490	37.7	77912	17.5
South Asia	671842	231647	34.5	216846	32.3	-14801	-2.2
East Asia	1112296	139727	12.6	151479	13.6	11752	1.1
Central Asia	414363	45197	10.9	16323	3.9	-28874	-7.0
Japan	37178	4379	11.8	10592	28.5	6213	16.7
DEVELOPING	8171488	909630	11.1	2579828	31.6	1670198	20.4
DEVELOPED	5228028	465486	8.9	1071456	20.5	605970	11.6
WORLD TOTAL	13399516	1375116	10.3	3651284	27.2	2276168	17.0

When considering all crop types modeled in Global AEZ (excluding silage maize, forage legumes and grasses) and mixing all three input levels, we conclude that a little more than one-quarter of the Earth's land surface (excluding Antarctica) can be regarded as suitable for crop cultivation. In developed regions about one-fifth comprises of land with rain-fed cultivation potential. In developing regions it amounts to about 30 percent. This estimate of land with cultivation potential (of course, also because of being 'gross' rather than 'net' available areas) is more than twice the area that was actually in use for cultivation during 1994-96 (according to FAOSTAT). Despite this optimistic aggregate picture, Table 37 indicates several regions where the rain-fed cultivation potential has already been exceeded or is nearly fully exhausted. Further details, in terms of suitability by input level, are shown

²⁸ Source: FAOSTAT, Rome.

in Table 39. Plate 46 (in Appendix XV) shows a map of areas with rain-fed cultivation potential.

By looking at all crop types, without consideration of the demand for different products, we may well over-estimate the *useful* extents of land with cultivation potential. Therefore, Table 38 was compiled by restricting the considered crop types to the three major cereals, namely wheat, rice, and grain-maize. Under these assumptions, an estimate of about 2.4 thousand million ha of land with rain-fed cultivation potential (VS+S+MS) was obtained. Of these, 1.5 thousand million ha were found in less developed countries and 0.9 thousand million ha in developed regions.

Table 38 Extents of land in use for crop cultivation (1994-96) and gross extents of land with potential for rain-fed wheat, grain-maize, or rice cultivation (VS+S+MS)

REGION	TOTAL LAND (1000 ha)	Land in use for crop cultivation (FAOSTAT 1994-96)		Land suitable for rain-fed cereals (VS+S+MS) (mixed inputs)		Balance	
		(1000 ha)	(%)	(1000 ha)	(%)	(1000 ha)	(%)
North America	2138498	225278	10.5	347237	16.2	121959	5.7
Eastern Europe	170952	81716	47.8	114214	66.8	32498	19.0
Northern Europe	172524	21556	12.5	39558	22.9	18002	10.4
Southern Europe	131643	45632	34.7	45283	34.4	-349	-0.3
Western Europe	109547	35143	32.1	61457	56.1	26314	24.0
Russian Federation	1674146	130055	7.8	214588	12.8	84533	5.0
Caribbean	23397	7601	32.5	7490	32.0	-111	-0.5
Central America	248353	35937	14.5	40017	16.1	4080	1.6
South America	1777573	114787	6.5	532101	29.9	417314	23.5
Oceania	793540	51782	6.5	71009	8.9	19227	2.4
Polynesia	56118	1379	2.5	2903	5.2	1524	2.7
Eastern Africa	639474	45975	7.2	198963	31.1	152988	23.9
Middle Africa	657061	24772	3.8	184683	28.1	159911	24.3
Northern Africa	794112	44134	5.6	74969	9.4	30835	3.9
Southern Africa	266428	17437	6.5	16196	6.1	-1241	-0.5
Western Africa	632996	65384	10.3	126083	19.9	60699	9.6
Western Asia	432992	46075	10.6	29520	6.8	-16555	-3.8
Southeast. Asia	444483	89578	20.2	75461	17.0	-14117	-3.2
South Asia	671842	231647	34.5	168461	25.1	-63186	-9.4
East Asia	1112296	139727	12.6	118169	10.6	-21558	-1.9
Central Asia	414363	45197	10.9	12286	3.0	-32911	-7.9
Japan	37178	4379	11.8	9999	26.9	5620	15.1
DEVELOPING	8171488	909630	11.1	1587302	19.4	677672	8.3
DEVELOPED	5228028	465486	8.9	903345	17.3	437859	8.4
WORLD TOTAL	13399516	1375116	10.3	2490647	18.6	1115531	8.3

To take yet another look at the Global AEZ crop suitability results, in Table 40 we present per capita land currently (i.e., average of 1994-96) in use for cultivation and per capita *net*²⁹ rain-fed land with cultivation potential for populations in 1995 and projected populations in 2050. In the calculations the population projections of the United Nations medium variant

²⁹ Net rain-fed land with cultivation potential excludes land requirements for infrastructure and settlement. In order to estimate land requirements for housing and infrastructure, we used a gridded population dataset of the year 1995, available from the World Data Center for Human Interaction in the Environment at the Center for International Earth Science Information Network (CIESIN, 2000). The data provides population counts and population density (people per square kilometer) for grid-cells of 5 minutes latitude/longitude. Housing and infrastructure requirements population density. They amount to 0.1 ha per person in areas with very low population density, and are estimated at 0.05 ha per person when population density is 35 persons per square kilometer, and they decline monotonously to 0.01 ha per person when the density reaches 3000 persons per square kilometer.

were used (United Nations, 1998). With very few exceptions (notably Australia, Russia, and North America), most regions were characterized by a use of arable land per person in the mid-1990s of some 0.1 to 0.4 ha; the world average in 1995 being about 0.25 ha/person for a world population of almost 5.7 billion people. The results suggest a considerable availability of resources suitable for agricultural uses. However, we do not hesitate to state that such increased use of cultivated land is neither likely (because of improvements in input use and technology leading to higher average per hectare output, and because of competition with other non-agricultural uses) nor desirable (because of obvious implications for bio-diversity and the carbon cycle).

Table 39 Gross extents with rain-fed cultivation potential (1000 ha) - maximizing technology mix³⁰

Region	Total land (1000 ha)	VS+S+MS Land with cultivation potential		High input level		Intermediate input level			Low input level				NS (1000 ha)
		(1000 ha)	(%)	VS (1000 ha)	S (1000 ha)	VS (1000 ha)	S (1000 ha)	MS (1000 ha)	VS (1000 ha)	S (1000 ha)	MS (1000 ha)	mS (1000 ha)	
11 North America	2138498	405499	19.0	91673	142981	3095	42713	77317	1	1266	46453	108847	1624153
21 Eastern Europe	170952	125883	73.6	21941	41914	1166	14713	34372	0	534	11243	9871	35202
22 Northern Europe	172524	44572	25.8	7700	20947	625	3684	9693	0	60	1863	6313	121640
23 Southern Europe	131643	59291	45.0	7922	10879	536	11935	18978	33	1875	7133	9605	62745
24 Western Europe	109547	66309	60.5	16421	21130	1340	11586	12522	0	101	3209	4556	38684
25 Russian Federation	1674146	238658	14.3	30416	72538	2658	36100	61572	0	1157	34217	50578	1384914
	2258812	534713	23.7	84400	167408	6325	78018	137137	33	3727	57665	80923	1643185
31 Caribbean	23397	11728	50.1	5883	3302	0	973	1313	0	62	195	879	10779
32 Central America	248353	57487	23.1	24891	13867	0	4888	9509	0	136	4196	11403	179461
	271750	69215	25.5	30774	17169	0	5861	10822	0	198	4391	12282	190240
41 South America	1777573	925299	52.1	393937	386480	973	23981	102205	0	1324	16399	68235	784038
51 Oceania	793540	120652	15.2	32240	35109	163	9131	32066	0	380	11563	34741	638148
52 Polynesia	56118	17860	31.8	9877	6586	0	286	1019	0	0	92	1796	36461
	849658	138512	16.3	42117	41695	163	9417	33085	0	380	11655	36537	674609
61 Eastern Africa	639474	276735	43.3	108320	92498	870	14592	47494	0	252	12709	39256	323485
62 Middle Africa	657061	364076	55.4	172064	135663	6	4311	48421	0	1	3610	38016	254969
63 Northern Africa	794112	108814	13.7	48246	26394	724	7803	18647	11	1450	5539	14055	671242
64 Southern Africa	266428	34118	12.8	2484	4694	516	7061	13602	22	748	4991	13050	219256
65 Western Africa	632996	195132	30.8	92246	70109	208	6019	24977	0	11	1562	13957	423904
	2990071	978875	32.7	423360	329358	2324	39786	153141	33	2462	28411	118334	1892856
71 Western Asia	432992	36441	8.4	1881	5023	281	4671	15498	1	972	8114	11661	384888
81 Southeast. Asia	444483	167490	37.7	96359	58401	24	1495	9860	0	0	1351	13580	263420
82 South Asia	671842	216846	32.3	116544	73409	184	4490	15965	4	324	5926	23338	431656
84 East Asia	1112296	151479	13.6	49793	45264	190	13573	34490	0	364	7805	34134	926682
85 Central Asia	414363	16323	3.9	503	782	337	1315	7840	0	223	5323	26669	371374
86 Japan	37178	10592	28.5	3039	2586	0	1649	2966	0	2	350	2564	24023
	2680162	562730	21.0	266238	180442	735	22522	71121	4	913	20755	100285	2017155
DEVELOPING	8171488	2579828	31.6	1123028	922472	4313	95458	350840	38	5867	77812	310029	5281615
DEVELOPED	5228028	1071456	20.5	211352	348084	9583	131511	249486	34	5375	116031	227075	3929509
WORLD TOTAL	13399516	3651284	27.2	1334380	1270556	13896	226969	600326	72	11242	193843	537104	9211124

VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable.

³⁰ For the definition of *maximizing technology mix*, see text at beginning of Section 5.4.

Table 40 Per capita land in use for cultivation and net rain-fed cultivation potential for cereals, populations of 1995 and projected populations in 2050

Region		Population ³¹		Total land (1000 ha)	Land in use for cultivation 1994-96		Rain-fed VS+S+MS net potential land (mixed input)		Rain-fed VS+S net potential land (high input)		Per capita land use (ha/pers.) 1994-96	Per capita VS+S+MS land (mixed input)		Per capita VS+S land (high input)	
Code	Name	1995	2050		(1000 ha)	(1000 ha)	%	(1000 ha)	%	(1000 ha)		%	1995	2050	1995
11	North America	296575	391692	2138498	225278	10.5	364949	17.1	211189	9.9	0.8	1.2	0.9	0.7	0.5
21	Eastern Europe	162047	130639	170952	81716	47.8	113295	66.3	57470	33.6	0.5	0.7	0.9	0.4	0.4
22	Northern Europe	93373	90384	172524	21556	12.5	40115	23.3	25782	14.9	0.2	0.4	0.4	0.3	0.3
23	Southern Europe	143352	114496	131643	45632	34.7	53362	40.5	16921	12.9	0.3	0.4	0.5	0.1	0.1
24	Western Europe	181377	170571	109547	35143	32.1	59678	54.5	33796	30.9	0.2	0.3	0.3	0.2	0.2
25	Russian Federation	148460	121256	1674146	130055	7.8	214792	12.8	92659	5.5	0.9	1.5	1.8	0.6	0.8
		728609	627346	2258812	314102	13.9	481242	21.3	226627	10.0	0.4	0.7	0.8	0.3	0.4
31	Caribbean	35559	51518	23397	7601	32.5	10555	45.1	8267	35.3	0.2	0.3	0.2	0.2	0.2
32	Central America	123473	222502	248353	35937	14.5	51738	20.8	34882	14.0	0.3	0.4	0.2	0.3	0.2
		159032	274020	271750	43538	16.0	62294	22.9	43149	15.9	0.3	0.4	0.2	0.3	0.2
41	South America	317477	534383	1777573	114787	6.5	832769	46.8	702375	39.5	0.4	2.5	1.6	2.2	1.3
51	Oceania	21423	31009	793540	51782	6.5	108587	13.7	60614	7.6	2.4	4.9	3.5	2.8	2.0
52	Polynesia	6890	14563	56118	1379	2.5	16074	28.6	14817	26.4	0.2	2.2	1.1	2.2	1.0
		28313	45572	849658	53161	6.3	124661	14.7	75431	8.9	1.9	4.2	2.7	2.7	1.7
61	Eastern Africa	219470	593048	639474	45975	7.2	249062	38.9	180736	28.3	0.2	1.1	0.4	0.8	0.3
62	Middle Africa	83271	274631	657061	24772	3.8	327668	49.9	276954	42.2	0.3	3.6	1.2	3.3	1.0
63	Northern Africa	157830	303173	794112	44134	5.6	97933	12.3	67176	8.5	0.3	0.6	0.3	0.4	0.2
64	Southern Africa	47335	65537	266428	17437	6.5	30706	11.5	6460	2.4	0.4	0.7	0.5	0.1	0.1
65	Western Africa	209380	526301	632996	65384	10.3	175619	27.7	146120	23.1	0.3	0.8	0.3	0.7	0.3
		717286	1762690	2990071	197703	6.6	880988	29.5	677446	22.7	0.3	1.2	0.5	0.9	0.4
71	Western Asia	149917	357461	432992	46075	10.6	32797	7.6	6214	1.4	0.3	0.2	0.1	0.0	0.0
81	Southeast. Asia	481106	784197	444483	89578	20.2	150741	33.9	139284	31.3	0.2	0.3	0.2	0.3	0.2
82	South Asia	1312671	2343713	671842	231647	34.5	195161	29.0	170958	25.4	0.2	0.1	0.1	0.1	0.1
84	East Asia	1295816	1570837	1112296	139727	12.6	136331	12.3	85551	7.7	0.1	0.1	0.1	0.1	0.1
85	Central Asia	70555	104770	414363	45197	10.9	14691	3.5	1157	0.3	0.6	0.2	0.1	0.0	0.0
86	Japan	125068	104921	37178	4379	11.8	9533	25.6	5063	13.6	0.0	0.1	0.1	0.0	0.0
		3285216	4908438	2680162	510528	19.0	506457	18.9	402012	15.0	0.2	0.1	0.1	0.1	0.1
	DEVELOPING	4510750	7746634	8171488	909630	11.1	2321845	28.4	1840950	22.5	0.2	0.5	0.3	0.4	0.2
	DEVELOPED	1171675	1154968	5228028	465486	8.9	964310	18.4	503492	9.6	0.4	0.8	0.8	0.4	0.4
	WORLD	5682425	8901602	13399516	1375116	10.3	3286156	24.5	2344442	17.5	0.2	0.6	0.4	0.4	0.3

³¹ Source: Projected data for 2050 from UN medium variant (Unites Nations, 1998).

5.5 Where irrigation matters

The results from Global AEZ have been examined to highlight areas where irrigation can make a significant contribution to land productivity. After processing each land unit of the land resources inventory, individual 5-minute latitude/longitude grid-cells were marked according to the potential impact that the application of irrigation has on suitable extents and production of cereals. The grid-cell results were aggregated according to impact classes by regions and countries, using an algorithm proceeding in six steps, as follows:

Algorithm:

For each land unit within each 5-minute latitude/longitude grid-cell in the land resources inventory, the algorithm proceeds in 5 steps:

- Step 1: Determine the crop (or multiple crop combination) which maximizes expected food grain output under rain-fed conditions;
- Step 2: Determine the crop (or multiple crop combination) which maximizes expected food grain output under irrigation conditions;
- Step 3: Determine the fraction of land in each 5 minute latitude/longitude grid-cell that is assessed as very suitable or suitable under irrigation (economically viable for irrigation). Test whether the irrigable share exceeds a specified minimum threshold SH_{min} ;
- Step 4: Combine rain-fed and irrigated production so as to maximize total output in each grid-cell;
- Step 5: Determine the ratio of potential cereal output under rain-fed and/or irrigation conditions to cereal potential under rain-fed conditions only, and
- Step 6: Aggregate results by country and region into 6 irrigation impact classes according to the following scheme:
 - 1: Areas where rain-fed cereal crops can be cultivated but irrigation is impossible or the irrigable share in a grid-cell is below the specified threshold SH_{min} ;
 - 2: The irrigable share in a grid-cell exceeds the minimum threshold SH_{min} ; irrigation increases potential cereal output of the respective grid-cell by less than 20 percent above rain-fed levels;
 - 3: As for 2, but contribution of irrigation to grid-cell production potential is 20 - 50 percent;
 - 4: As for 2, but contribution of irrigation to grid-cell production potential is 50 - 100 percent;
 - 5: As for 2, but contribution of irrigation to grid-cell production potential is > 100 percent and
 - 6: No rain-fed production possible and no or too little suitability under irrigation.

By definition, there is no or little contribution from irrigation to the production potential in areas grouped in impact classes 1, 2, and 6. On the other hand, the potential contribution from irrigation is particularly great in impact classes 4 and 5. Both the impact of irrigation on suitable extents and cereal production potential were quantified. Results were compiled for different levels of minimum threshold SH_{min} , namely of 1%, 5%, 10% and 25%. Summaries are available in form of tables and maps.

The analysis provides interesting insights regarding the potential role of irrigation in the various regions:

- Full exploitation of potential irrigable land increases the global gross extent of suitable land (VS+S+MS) for cereals by 6 to 9 percent³² for the world as a whole over and above the land potentially suitable under rain-fed conditions (see Table 41). Regional results vary substantially, namely between 3 percent (for South America) and 69 percent (for Western Asia).
- The impact of irrigation is more pronounced on potential production than on potential area. The cereal production potential increases by 30 to 40 percent (see Table 41). The

³² Depends on assumptions regarding minimum size of irrigable land tracts considered for irrigation (SH_{min}).

regions with the largest relative increase are Oceania, Northern and Southern Africa, Central and Western Asia.

Table 41 Potential impact of irrigation on global cereal suitability and production

Irrigation threshold <i>SH_{min}</i>	Land with suitability for irrigation:		Contribution of irrigation to:	
	Share in total suitable land (percent)	Share of impact classes 4 and 5 in total irrigable land	Total suitable land (percent)	Potential production (percent)
1 percent	34.6	52.1	8.8	41.7
5 percent	33.2	53.3	8.4	40.0
10 percent	31.2	54.9	7.8	37.4
25 percent	24.6	59.9	5.8	29.2

Table 42 Rain-fed share in total area suitable for cereals, by impact class

NAME	SHARE IN TOTAL SUITABLE AREA	SHARE IN IRRIGATION IMPACT CLASS				
		Class1 Rain-fed	Class 2 0-20 %	Class 3 20-50 %	Class 4 50-100 %	Class 5 >100 %
North America	90	100	99	96	92	43
Eastern Europe	97	100	100	96	80	22
Northern Europe	97	100	99	87	63	--
Southern Europe	93	100	99	97	91	61
Western Europe	98	100	99	95	95	31
Russian Fed.	89	100	99	93	85	14
	93	100	99	94	86	20
Caribbean	96	100	100	96	94	88
Central America	91	100	99	96	90	54
	92	100	99	96	91	58
South America	96	100	99	96	93	73
Oceania	67	100	99	99	96	47
Polynesia	100	100	100	98	100	100
	69	100	99	99	96	47
Eastern Africa	95	100	100	99	97	51
Middle Africa	98	100	99	95	96	93
Northern Africa	79	100	100	95	94	30
Southern Africa	77	100	100	99	98	39
Western Africa	95	100	99	96	95	62
	94	100	99	97	96	50
Western Asia	56	100	100	99	99	15
Southeast. Asia	97	100	100	95	85	62
South Asia	94	100	100	99	98	74
East Asia	89	100	99	97	96	57
Central Asia	31	100	99	98	95	14
Japan	97	100	95	80	64	--
	91	100	99	97	96	59
DEVELOPING	94	100	99	97	95	57
DEVELOPED	89	100	99	95	91	40
WORLD TOTAL	92	100	99	96	94	51

- In about 17 percent of gross suitable areas for rain-fed and/or irrigation conditions the share of supplementary or full irrigation would increase potential output by more than 50 percent above rain-fed levels. In another 11 percent of these suitable areas, potential output would benefit from irrigation between 20 to 50 percent.
- Overall, application of irrigation has a slightly higher impact in the developed countries than in developing countries, for both increases in extents of arable areas (13 and 7

percent, respectively) and potential output (47 and 38 percent, respectively for developed and developing regions)³³.

Table 43 Rain-fed share in total potential cereals production, by impact class

REGION	SHARE IN TOTAL PRODUCTION	SHARE IN IRRIGATION IMPACT CLASS				
		Class1 Rain-fed	Class 2 0-20 %	Class 3 20-50 %	Class 4 50-100 %	Class 5 >100 %
North America	74	100	92	76	58	18
Eastern Europe	88	100	93	74	46	8
Northern Europe	92	100	92	77	65	--
Southern Europe	73	100	93	76	53	19
Western Europe	91	100	93	75	59	11
Russian Fed.	78	100	93	72	46	5
	84	100	93	74	48	9
Caribbean	70	100	88	73	58	38
Central America	69	100	89	75	58	24
	69	100	89	74	58	26
South America	80	100	92	77	59	28
Oceania	28	100	91	74	57	14
Polynesia	97	100	95	78	65	37
	31	100	92	74	57	14
Eastern Africa	72	100	88	75	59	16
Middle Africa	83	100	89	75	60	37
Northern Africa	47	100	88	74	59	9
Southern Africa	35	100	87	73	54	12
Western Africa	73	100	90	76	60	20
	70	100	89	75	59	15
Western Asia	21	100	89	73	56	3
Southeast. Asia	87	100	92	75	61	47
South Asia	62	100	91	75	59	28
East Asia	76	100	95	75	59	20
Central Asia	13	100	94	69	48	4
Japan	96	100	94	78	64	--
	70	100	93	75	59	23
DEVELOPING	73	100	91	76	59	21
DEVELOPED	68	100	92	75	56	14
WORLD TOTAL	71	100	92	75	59	19

The geographical distribution of irrigation impact classes for areas suitable for cereal production is shown in Plate 47.

5.6 Best cereal

Another interesting application with results of AEZ concerns the comparison of agronomic suitability among cereals³⁴ and selection of the cereal type with the highest overall suitability for individual land units of each 5' grid-cell. It is very well possible, for instance, that a certain land unit is very suitable for pearl millet and only moderately suitable for grain maize. Pearl millet would be the crop that is best agronomically suited to that particular environment, while the grain yield of the moderately suitable maize could exceed the yield of the millet. Therefore, also a comparison is presented in terms of food production, using nutritive values and conversion rates as weights. A third option is to compare yields and

³³ Calculated taking inverse of relevant entries in column 2 of Table 42 and 43, respectively.

³⁴ Cereals in Global AEZ include: wheat, barley, rye, rice, maize, sorghum, foxtail millet and pearl millet.

production in value terms. Weighting factors for crop selection by output value and nutritive content are the following:

Value and nutritive weighting factors of cereals used for determining ‘best’ crop

	Unit Value (\$/ton)	Calorie content (kcal/100 g)	Protein content (g/kg)	Food conversion rate (%)	Food energy weight	Nutritive weight
WHEAT	161	334	122	78	261	299
RICE	263	360	67	67	241	259
MAIZE	142	356	95	92	328	362
BARLEY	138	337	75	82	276	301
SORGHUM	126	343	101	95	326	364
RYE	124	319	110	80	255	290
MILLET	125	340	97	95	323	360

Plate 48 in Appendix XV presents a map showing the ‘best’ cereal in terms of agronomic suitability, Plate 49 shows a map of the ‘best’ cereal in terms of food energy, and Plate 50 displays the ‘best’ cereal according to output value, using average 1994-98 world export unit values for comparison.

When selecting among cereal crops on the basis of expected value of output, then wheat, rice and grain maize each dominate in around 30 percent of the total suitable areas. The remaining cereals (barley, rye, sorghum, foxtail millet and pearl millet) together would be chosen in merely 6 percent of the area. In terms of production, grain maize provides the largest share of some 40 percent, followed by wheat and rice, each contributing 28 percent (see Table 44).

The picture changes somewhat when nutritive factors are used for weighting crop production prior to selecting a ‘best’ crop. In this case, grain-maize takes a somewhat larger share of 42 percent in total suitable area while the share of rice is decreased in comparison to a selection based on price rather than nutrition (from 30 to 22 percent). Results for wheat/barley remain nearly the same. These differences in area distribution are also reflected in the resulting output pattern. Grain-maize accounts for 49 percent of total output when selecting among cereals according to nutritive content, rice contributes 20 percent, wheat and barley together account for 25 percent, and close to 7 percent go to sorghum, rye and millet (see Table 45.).

Table 44 Distribution of “best” crops when using as selection criterion the crop output value per land unit

REGION	GROSS SUIT- ABLE AREA (VS+S+MS) 10 ⁶ ha	SHARE IN SUITABLE AREA (PERCENT)				POTENTIAL USABLE PRODUCTION 10 ⁶ tons	SHARE IN POTENTIAL PRODUCTION (PERCENT)			
		WHEAT, BARLEY	RICE	MAIZE	OTHER CEREALS		WHEAT, BARLEY	RICE	MAIZE	OTHER CEREALS
North America	280.3	81.6	0.5	17.5	0.4	847.8	79.0	0.3	20.5	0.2
Eastern Europe	89.0	100.0	0.0	0.0	0.0	296.1	100.0	0.0	0.0	0.0
Northern Europe	35.9	99.7	0.0	0.0	0.3	110.6	99.9	0.0	0.0	0.1
Southern Europe	21.1	99.3	0.4	0.1	0.2	68.1	99.5	0.3	0.1	0.1
Western Europe	47.5	99.8	0.0	0.2	0.0	171.5	99.9	0.0	0.1	0.0
Russian Fed.	168.9	99.7	0.0	0.1	0.2	378.4	99.7	0.0	0.2	0.1
	362.5	99.8	0.0	0.1	0.1	1024.9	99.8	0.0	0.1	0.1
Caribbean	6.6	0.0	76.2	23.8	0.0	19.2	0.0	74.3	25.6	0.0
Central America	32.6	9.4	56.4	27.9	6.3	96.9	6.8	54.8	34.7	3.8
	39.2	7.8	59.7	27.2	5.2	116.1	5.6	58.0	33.2	3.1
South America	527.0	7.7	64.8	24.7	2.7	1505.3	6.2	62.1	29.6	2.1
Oceania	67.4	37.1	2.7	42.7	17.5	177.7	29.7	2.4	54.7	13.1
Polynesia	5.0	0.0	93.3	6.5	0.2	13.5	0.0	92.2	7.7	0.1
	72.3	34.6	8.9	40.2	16.3	191.2	27.6	8.7	51.4	12.2
Eastern Africa	189.4	4.4	13.0	74.2	8.4	630.9	2.3	11.2	82.2	4.3
Middle Africa	200.2	0.3	58.2	37.7	3.8	612.2	0.1	51.9	45.7	2.2
Northern Africa	76.5	5.6	8.6	70.4	15.4	269.9	2.8	7.1	82.4	7.7
Southern Africa	8.7	9.8	0.0	55.7	34.5	19.1	6.8	0.0	69.1	24.1
Western Africa	143.8	0.0	26.4	56.0	17.7	453.3	0.0	22.7	67.4	9.9
	618.6	2.3	30.0	57.4	10.3	1985.5	1.2	25.7	67.5	5.6
Western Asia	10.5	100.0	0.0	0.0	0.0	24.2	100.0	0.0	0.0	0.0
Southeast. Asia	87.2	2.5	85.4	11.8	0.3	244.4	1.0	86.2	12.5	0.2
South Asia	184.8	0.8	15.9	68.3	14.9	613.3	0.5	14.5	73.8	11.3
East Asia	113.0	10.8	21.0	51.0	17.2	298.9	9.9	21.8	59.6	8.6
Central Asia	6.0	98.9	1.1	0.0	0.0	10.7	98.7	1.3	0.0	0.0
Japan	6.6	60.7	36.5	2.8	0.0	22.4	65.3	32.1	2.5	0.0
	397.6	6.5	32.7	48.9	11.9	1189.8	5.1	31.3	55.6	8.0
DEVELOPING	1591.3	5.6	42.9	43.4	8.0	4811.9	4.0	39.3	51.7	5.0
DEVELOPED	716.7	86.4	0.8	10.9	1.9	2072.7	84.9	0.7	13.1	1.2
WORLD TOTAL	2308.0	30.7	29.8	33.3	6.1	6884.7	28.4	27.7	40.1	3.9

Table 45 Distribution of “best” crops when using nutritive values as weights in crop selection

REGION	GROSS SUIT- ABLE AREA (VS+S+MS) 10 ⁶ ha	SHARE IN SUITABLE AREA (PERCENT)				POTENTIAL USABLE PRODUCTION 10 ⁶ tons	SHARE IN POTENTIAL PRODUCTION (PERCENT)			
		WHEAT, BARLEY	RICE	MAIZE	OTHER CEREALS		WHEAT, BARLEY	RICE	MAIZE	OTHER CEREALS
North America	278.2	66.1	0.3	31.5	2.1	839.3	64.1	0.2	34.5	1.2
Eastern Europe	89.0	99.5	0.0	0.5	0.0	296.0	99.4	0.0	0.6	0.0
Northern Europe	36.0	99.2	0.0	0.0	0.8	110.8	99.7	0.0	0.0	0.3
Southern Europe	21.2	89.3	0.0	10.5	0.2	68.0	86.8	0.0	13.2	0.1
Western Europe	47.6	99.6	0.0	0.3	0.1	171.7	99.7	0.0	0.3	0.1
Russian Fed.	171.1	97.8	0.0	1.8	0.3	380.0	97.9	0.0	1.9	0.2
	364.9	98.1	0.0	1.6	0.3	1026.4	98.1	0.0	1.8	0.1
Caribbean	5.7	0.0	44.6	55.3	0.0	17.9	0.0	42.0	57.9	0.0
Central America	30.3	7.3	42.3	42.6	7.9	93.7	4.8	41.3	49.0	4.9
	36.0	6.1	42.7	44.6	6.7	111.6	4.0	41.4	50.5	4.1
South America	515.2	4.2	58.0	32.6	5.2	1493.1	3.0	55.4	37.3	4.2
Oceania	66.9	33.7	0.4	39.7	26.2	179.5	26.3	0.3	51.5	21.9
Polynesia	4.7	0.0	92.0	6.9	1.2	13.0	0.0	90.8	7.8	1.4
	71.5	31.5	6.4	37.5	24.6	192.4	24.6	6.4	48.5	20.5
Eastern Africa	188.5	3.2	3.7	79.6	13.6	650.7	1.6	3.2	86.7	8.5
Middle Africa	195.8	0.2	47.0	46.7	6.1	618.2	0.1	40.4	55.3	4.2
Northern Africa	77.1	5.7	1.4	73.9	19.0	277.2	2.8	1.2	85.6	10.4
Southern Africa	8.8	6.9	0.0	43.7	49.4	19.5	4.7	0.0	55.1	40.3
Western Africa	140.2	0.0	15.2	62.8	22.0	456.0	0.0	13.3	73.4	13.4
	610.3	1.9	19.9	63.9	14.3	2021.6	1.0	16.5	73.7	8.8
Western Asia	10.5	100.0	0.0	0.0	0.0	24.1	100.0	0.0	0.0	0.0
Southeast. Asia	81.9	2.4	55.1	42.0	0.6	240.3	0.9	53.0	45.7	0.4
South Asia	185.1	0.7	5.2	71.9	22.2	638.5	0.4	5.0	77.6	17.0
East Asia	112.2	2.9	1.2	72.2	23.7	314.0	2.4	1.2	83.1	13.4
Central Asia	5.9	94.6	0.8	4.6	0.0	10.6	90.6	1.0	8.4	0.0
Japan	6.5	32.7	1.9	65.3	0.0	24.5	32.4	1.3	66.2	0.0
	391.7	3.6	14.4	64.6	17.4	1227.9	2.4	13.3	71.9	12.4
DEVELOPING	1561.9	3.7	31.7	52.7	11.8	4866.7	2.4	28.4	61.0	8.2
DEVELOPED	716.5	79.1	0.2	17.4	3.4	2069.7	77.3	0.1	20.1	2.5
WORLD TOTAL	2278.4	27.4	21.8	41.6	9.2	6936.4	24.7	20.0	48.8	6.5

5.7 Multiple cropping land productivity

A multiple cropping zones classification (see Section 4.7) is used to determine feasible crop combinations (sequential cropping patterns) in each 5-minute latitude/longitude grid-cell of the land resources inventory.

In our calculations, only those crops qualify which are individually suitable and which can be combined within the available growing period (LGP for rain-fed conditions, or $LGP_{t=5}$ for irrigated conditions). Dryland crops are allowed to overlap partly (relay cropping with less than 30% overlap). Zones where relay cropping is required for double or triple cropping are referred to as 'limited' double (C) or 'limited' triple cropping (F) zones. It is assumed that relay cropping is not applicable to wetland-wetland or wetland-dryland crop combinations. An example of results of an assessment of land production potential of cereals by multiple cropping zones is presented in Table 46. This table is complemented by Plates 53 and 54, which present maps showing the global distribution of the land production potential of cereals, under rain-fed and rain-fed plus irrigated conditions.

The selection of an optimal cereal crop combination can be described as the task of matching the requirements of the suitable crop types with the characteristics of a particular grid-cell in such a way that a maximum grain production can be achieved. The AEZ algorithm uses a scheme of eight generic crop groups, based on a distinction of crop growth cycle length and thermal requirements, to determine feasible (within-year) sequential multi-cropping patterns. Each crop LUT belongs to one of these eight groups.

In the case of a single-cropping zone the selection of the best grain is easy. The algorithm compares the grid-cell characteristics with the requirements of all cereal LUTs. Among those grains that fit, the algorithm selects the one producing the highest potential production. In the case of multi-cropping the selection is more difficult. The algorithm cannot practically test all possible combinations of the 83 available crop types - this would multiply the time needed for the calculations. Instead, only those crops are tested as a second or third grain, that have the highest yield in each of the eight generic groups. The rules for constructing cropping patterns have been designed to make sure that the algorithm uses typical crop sequences in cultivation cycles. For instance, in the typical double-cropping areas around Shanghai, the algorithm would select a long-cycle rice or maize crop as the most productive summer crop, and winter wheat or barley (depending on which is more productive) as the winter crop, provided the combination of both grains fits within the LGP of the particular grid-cell. In a triple-cropping zone either three short-cycle crops or two long-cycle crops are permitted.

The results in Table 46 are shown as percentage distributions over eight multiple cropping zones, both for suitable land (VS+S+MS) and attainable production from these areas. According to our estimation from an example calculation for cereals, 46 percent of the land globally suitable for rain-fed cereals falls in zone B (i.e., single cropping) providing 42 percent of the cereal production potential. Some 39 percent of the suitable area could produce two crops per year (zones C, D, E) contributing 38 percent of the global cereal production potential. The remaining 15 percent of suitable areas could support three crops per annum (zones F, G, H) and produce almost 20 percent of the global cereal production potential.

Table 46 Gross area and production potential for cereals at intermediate input level, by multiple cropping zones and major world region

Region	Total land area (10 ⁶ ha)	Share of total suitable area and multiple cropping production potential for cereals at intermediate input level																	
		Land with cultivation potential VS+S+MS (10 ⁶ ha)	Multiple cropping production (10 ⁶ tons)	Zone A		Zone B		Zone C		Zone D		Zone E		Zone F		Zone G		Zone H	
				Area (%)	Prod. (%)	Area (%)	Prod. (%)	Area (%)	Prod. (%)	Area (%)	Prod. (%)	Area (%)	Prod. (%)	Area (%)	Prod. (%)	Area (%)	Prod. (%)	Area (%)	Prod. (%)
North America	2138.5	296.7	1266.3	0.0	0.0	37.9	26.1	18.8	19.0	13.7	14.5	10.1	12.5	6.2	8.3	11.3	16.5	1.9	3.2
Eastern Europe	171.0	105.0	433.0	0.0	0.0	95.0	94.8	5.0	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern Europe	172.5	36.2	133.7	0.0	0.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Southern Europe	131.6	36.2	132.4	0.0	0.0	73.2	67.9	23.1	27.5	3.7	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Western Europe	109.5	57.0	247.8	0.0	0.0	97.4	97.6	2.5	2.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Russian Federation	1674.1	187.7	547.1	0.0	0.0	98.8	98.2	1.1	1.6	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Caribbean	23.4	8.8	26.8	0.0	0.0	0.2	0.1	0.6	0.9	70.7	68.6	0.0	0.0	22.1	20.5	0.0	0.0	6.4	8.5
Central America	248.4	38.8	126.7	0.0	0.0	39.5	32.9	8.3	10.0	32.6	34.8	0.0	0.0	16.6	17.3	0.0	0.0	3.0	4.7
South America	1777.8	558.4	2055.0	0.0	0.0	9.7	7.5	7.0	6.5	46.1	38.5	2.0	2.7	17.6	16.8	5.9	10.8	11.7	16.7
Oceania	793.5	84.0	246.0	0.0	0.0	78.3	68.3	7.0	7.7	4.8	6.5	4.5	6.7	2.1	3.9	3.3	6.8	0.0	0.0
Polynesia	56.1	2.7	9.2	0.0	0.0	0.0	0.0	6.2	7.1	56.4	55.2	0.0	0.0	13.1	13.1	0.0	0.0	24.3	23.9
Eastern Africa	639.5	209.4	734.2	0.0	0.0	49.1	49.3	27.1	29.8	21.4	18.8	0.0	0.0	1.6	1.0	0.0	0.0	0.9	0.8
Middle Africa	657.1	213.9	623.0	0.0	0.0	20.9	24.9	9.9	12.7	46.7	42.0	0.0	0.0	16.0	13.2	0.0	0.0	6.6	6.7
Northern Africa	794.1	69.3	235.8	0.1	0.1	62.2	60.5	18.5	24.3	19.3	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Southern Africa	266.4	23.9	60.3	0.0	0.1	74.6	65.1	17.4	19.6	3.4	4.9	2.2	4.5	0.9	1.4	1.1	3.1	0.3	1.2
Western Africa	633.0	161.4	484.6	0.0	0.0	46.6	48.7	13.6	18.0	32.0	27.0	0.0	0.0	7.7	6.1	0.0	0.0	0.1	0.1
Western Asia	433.0	22.1	65.1	0.0	0.0	98.2	97.8	1.8	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Southeast. Asia	444.5	73.4	233.0	0.0	0.0	0.0	0.0	1.8	2.1	81.7	77.9	0.9	1.1	6.7	6.7	0.0	0.1	8.9	11.5
South Asia	671.8	158.6	605.4	0.0	0.0	73.3	70.6	13.1	15.2	10.0	9.3	2.4	3.1	0.6	0.6	0.3	0.4	0.4	0.5
East Asia	1112.3	93.8	366.5	0.0	0.0	45.5	28.6	11.8	9.6	6.2	5.7	12.7	19.8	12.2	17.2	8.3	13.5	3.3	5.5
Central Asia	414.4	10.1	28.7	4.2	4.0	91.3	89.6	2.5	4.0	1.8	2.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Japan	37.2	8.1	34.0	0.0	0.0	51.2	47.2	17.7	17.7	21.7	24.7	9.4	10.1	0.0	0.1	0.0	0.0	0.0	0.0
DEVELOPING	8171.5	1644.6	5654.3	0.0	0.0	33.0	31.0	11.7	13.0	34.7	29.8	1.7	2.7	10.6	10.2	2.5	4.9	5.7	8.0
DEVELOPED	5228.0	810.9	3039.7	0.0	0.0	72.2	63.4	9.9	11.1	5.9	7.1	4.2	5.9	2.5	3.8	4.5	7.4	0.7	1.3
WORLD TOTAL	13399.5	2455.4	8694.0	0.0	0.0	46.0	42.3	11.1	12.4	25.2	21.9	2.5	3.8	7.9	7.9	3.2	5.8	4.1	5.7

- A. Zone of no cropping (on average, too cold or too dry for rain-fed crops)
- B. Zone of single cropping
- C. Zone of limited double cropping (relay cropping; single wetland rice may be possible)
- D. Zone of double cropping (sequential cropping; wetland rice not possible)
- E. Zone of double cropping (sequential cropping; one wetland rice crop possible)
- F. Zone of limited triple cropping (partly relay cropping; no third crop possible in case of two wetland rice crops)
- G. Zone of triple cropping (sequential cropping of three short-cycle crops; two wetland rice crops possible)
- H. Zone of triple rice cropping (sequential cropping of three wetland rice crops possible)

5.8 Current land cover

Presently some 1.5 billion hectares of land is used for agriculture (average over years 1994-96 according to FAOSTAT). Comparison of potentially arable land with presently used land requires that within the potential arable land non-agricultural land uses are accounted for. Land needed for infrastructure and human settlement along with land set aside for, e.g. forest ecosystems in natural reserves, must be excluded, or at least must be accounted for separately.

Table 47 Distribution of aggregate land cover classes by world region

Region	Aggregate land cover classes* (%)											
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)	(xi)	(xii)
North America	6.3	11.1	26.3	7.6	4.0	2.6	1.0	8.5	6.8	25.2	0.4	0.1
Eastern Europe	0.5	2.1	9.9	32.2	51.6	0.1	0.0	0.0	2.1	0.0	1.4	0.0
Northern Europe	1.5	10.8	41.3	12.6	14.4	0.1	0.7	0.4	11.2	6.2	0.8	0.0
Southern Europe	0.6	14.1	19.8	21.8	35.6	0.6	0.0	2.9	4.0	0.3	0.3	0.0
Western Europe	0.6	6.2	13.5	6.0	68.8	0.2	0.1	0.2	2.5	0.7	1.3	0.0
Russian Federation	4.0	24.6	38.3	5.8	8.7	0.3	3.4	0.4	3.6	10.6	0.2	0.0
Caribbean	8.8	12.8	26.3	0.6	32.3	0.0	6.6	0.3	11.6	0.1	0.4	0.0
Central America	14.3	15.6	29.8	7.2	12.1	0.8	0.1	17.5	2.6	0.0	0.1	0.0
South America	13.3	15.4	39.2	14.8	3.4	2.9	0.3	5.6	2.9	2.0	0.1	0.0
Oceania	27.0	33.5	4.8	0.0	6.4	0.0	0.0	26.1	2.1	0.0	0.1	0.0
Polynesia	14.7	5.0	59.9	5.2	3.1	1.0	0.0	0.0	8.3	0.0	0.0	2.8
Eastern Africa	25.8	23.5	5.1	10.5	15.4	0.0	0.0	15.9	3.7	0.0	0.0	0.0
Middle Africa	15.5	31.7	29.3	4.8	5.2	0.0	0.1	11.6	1.9	0.0	0.0	0.0
Northern Africa	9.7	8.3	0.6	1.4	0.9	0.2	0.3	78.1	0.4	0.0	0.0	0.0
Southern Africa	38.4	0.6	1.6	17.8	7.2	0.0	0.1	33.9	0.3	0.0	0.1	0.0
Western Africa	25.4	16.3	2.1	6.1	2.3	0.1	0.5	46.0	1.2	0.0	0.0	0.0
Western Asia	5.2	0.5	1.8	6.5	5.8	0.3	0.0	78.5	1.2	0.1	0.1	0.0
Southeast. Asia	3.8	3.0	51.3	10.7	9.1	17.6	0.0	0.1	4.0	0.0	0.2	0.0
South Asia	7.3	4.5	5.9	8.1	21.1	12.0	0.1	37.8	1.5	1.5	0.1	0.0
East Asia	25.1	6.9	10.0	8.2	6.7	9.6	0.0	30.9	1.8	0.8	0.1	0.0
Central Asia	33.2	1.7	2.2	14.3	9.0	2.1	0.0	32.1	3.7	1.4	0.2	0.0
Japan	3.9	12.5	55.5	7.7	2.9	8.4	1.1	0.3	6.5	0.0	1.2	0.0
DEVELOPING	17.1	11.9	17.8	9.3	7.2	4.1	0.2	29.3	2.2	0.7	0.1	0.0
DEVELOPED	8.1	18.5	26.6	7.1	9.9	1.3	1.6	7.7	4.9	13.9	0.4	0.0
WORLD TOTAL	13.6	14.5	21.2	8.5	8.3	3.0	0.7	20.9	3.3	5.9	0.2	0.0

* (i) Grassland (v) Cropland 1 (ix) Water (coastal fringes)
(ii) Woodland (vi) Cropland 2 (x) Ice, cold desert
(iii) Forest (vii) Wetland (xi) Urban
(iv) Mosaics including cropland (viii) Desert and barren land (xii) Undefined

In the Global AEZ assessment we have used an aggregate ecosystems data set derived from a Global Land Cover Characteristics (GLCC) Database³⁵ with 30 arc-seconds latitude/longitude resolution (EROS Data Center, 2000). The GLCC database provides interpretations of 1-km AVHRR data (obtained during April 1992 through March 1993) according to various legends. We applied the Olson Global Ecosystem classification (Olson, 1994). This classification distinguishes about 100 ecosystem classes (not all classes are present in the data set), which were aggregated into broad ecosystem classes (see Plate 55)

³⁵ The data set was compiled from remotely-sensed multi-temporal AVHRR data of 1992/93 by the US Geological Survey (USGS) Earth Resources Observation System (EROS) Data Centre, the University of Nebraska-Lincoln (UNL), and the Joint Research Centre (JRC) of the European Commission.

for use with Global AEZ results. The distribution of these aggregate land-cover classes by major world region is presented in Table 47.

Table 48 Land under forest ecosystems with potential for rain-fed cultivation of major cereals³⁶

Region	Total of forest ecosystems (mill. ha)	VS+S for wheat, rice, maize (high input)				VS+S+MS for wheat, rice, maize (mixed inputs)			
		Total (mill. ha)	Under forest ecosystems			Total (mill. ha)	Under forest ecosystems		
			Extent (mill. ha)	% of forest	% of suitable		Extent (mill. ha)	% of forest	% of suitable
North America	562.1	192.9	64.9	11.6	33.7	342.0	114.8	20.4	33.6
Eastern Europe	17.0	57.8	0.9	5.3	1.6	110.9	3.9	23.2	3.6
Northern Europe	63.6	24.0	2.7	4.2	11.2	38.2	8.2	12.9	21.4
Southern Europe	23.9	14.0	0.8	3.4	5.9	43.6	3.5	14.4	7.9
Western Europe	14.3	35.4	0.5	3.4	1.4	58.9	2.1	14.4	3.5
Russian Federation	641.7	74.2	22.2	3.5	29.9	211.5	57.5	9.0	27.2
	760.5	205.4	27.1	3.6	13.2	463.2	75.2	9.9	16.2
Caribbean	3.8	4.2	0.3	8.7	7.9	7.3	0.6	16.3	8.6
Central America	66.4	22.0	4.7	7.0	21.2	39.1	9.4	14.2	24.1
	70.2	26.2	5.0	7.1	19.0	46.4	10.0	14.3	21.6
South America	680.5	314.0	103.8	15.2	33.0	528.3	186.6	27.4	35.3
Oceania	38.1	33.5	4.1	10.9	12.4	70.2	10.5	27.6	15.0
Polynesia	33.6	2.3	0.3	1.0	14.8	2.9	0.6	1.8	20.5
	71.7	35.8	4.5	6.2	12.5	73.1	11.1	15.5	15.2
Eastern Africa	32.8	118.8	2.4	7.2	2.0	196.2	5.4	16.4	2.7
Middle Africa	190.2	112.2	17.0	9.0	15.2	183.4	33.8	17.8	18.4
Northern Africa	4.9	52.7	0.4	7.7	0.7	74.0	0.5	10.8	0.7
Southern Africa	4.2	2.7	0.0	0.7	1.1	15.6	0.5	12.1	3.2
Western Africa	13.5	82.1	1.0	7.6	1.3	123.3	2.1	15.8	1.7
	245.6	368.5	20.8	8.5	5.6	592.5	42.4	17.3	7.2
Western Asia	7.6	4.0	0.1	1.0	1.9	28.6	1.0	13.1	3.5
Southeast. Asia	207.4	54.0	6.2	3.0	11.5	71.8	10.5	5.1	14.7
South Asia	39.6	116.7	2.1	5.3	1.8	153.9	3.4	8.6	2.2
East Asia	111.7	57.9	1.7	1.5	2.9	108.1	5.7	5.1	5.3
Central Asia	8.7	1.1	0.2	2.1	16.6	11.9	0.7	8.3	6.0
Japan	20.6	4.8	0.6	3.1	13.4	9.2	2.3	11.3	25.3
	388.0	234.5	10.8	2.8	4.6	354.9	22.7	5.9	6.4
DEVELOPING	1404.8	944.6	140.1	10.0	14.8	1544.3	261.0	18.6	16.9
DEVELOPED	1381.4	436.7	96.8	7.0	22.2	884.6	202.8	14.7	22.9
WORLD TOTAL	2786.1	1381.3	236.9	8.5	17.2	2428.9	463.8	16.6	19.1

As an example of combining AEZ results with spatial land-cover information, the extent of land with cultivation potential presently under forest ecosystems was estimated by overlaying the current land cover according to the GLCC database onto land with rain-fed cultivation potential. This revealed that some 464 million hectares of land with cultivation potential (VS, S, or MS) for wheat, rice, or grain-maize coincides with land dominantly classified as forest ecosystem. Around 8.5 percent, i.e., about 237 million hectares, of the area classified as forest ecosystems was assessed as very suitable or suitable (VS+S) for cultivation of these crops at high level of inputs. On the other hand, the analysis shows that globally almost 85

³⁶ In some countries the extents of forest ecosystems derived from the GLCC exceed the area of forest and woodland published by FAO. In such cases, the estimates of suitable areas under forest ecosystems were adjusted proportionally. Suitable extents are also adjusted for housing and infrastructure land requirements using a spatially explicit gridded global 1995 population distribution database (CIESIN, 2000).

percent of forest ecosystems are considered not or at best marginally suitable for these major cereal crops.

Table 48, presenting regional and global extents of land with cereal crop cultivation potential under GLCC forest ecosystems, shows rather wide variations among regions. In the Russian Federation, for example, only 9 percent of the land with forest ecosystems are adjudged having cultivation potential for one or more of the three major cereals, while in South America this share is as high as 27 percent. Only 3.5 percent of forest ecosystems in Russia is considered to be very suitable or suitable (VS+S) for the three cereal crops; in South America the respective value is 15 percent.

Also, we have estimated as to how important the land with cereal cultivation potential covered by forest ecosystems is within the overall potential. Our estimation suggests that close to 19 percent of the land with cultivation potential (VS+S+MS) is under forest ecosystems (i.e., 464 million hectares out of a total with cultivation potential of 2.43 thousand million hectares). A similar share, 17 percent (i.e., 237 million ha out of 1.38 thousand million ha), holds for very suitable and suitable lands. On a regional scale, the largest shares of land with crop production potential currently under forest are found in South and North America where more than one third of the potentially cultivable land determined by AEZ is classified as dominantly forest ecosystems according to GLCC. Considerable potentials with forest land cover were also assessed in the sub-humid and humid zones of Central America and Middle Africa. Our results indicate that relatively more land with cultivation potential for major cereals is covered by forest ecosystems in developed countries (about 23 percent) than in developing countries (about 17 percent).

5.9 Climate sensitivity

Our experiences with various climate sensitivity scenarios and preliminary results with GCM based climate scenarios underpin the appropriateness of the AEZ methods for climate change impact assessments. It confirms findings of earlier work with AEZ applications in case studies of Kenya (Fischer and van Velthuisen, 1996) and Nigeria (Voortman *et al.*, 1999), demonstrating that AEZ is very flexible in capturing all three types of impacts, namely on yields, on extents suitable for crop cultivation, and on changes in number of crops per year (sequential multi-cropping). It thus accounts for a wide range of rational adaptations, i.e., simulating impacts to 'smart' farmers. Recently, a number of experiments with GCM derived climate change scenarios were completed. A detailed report with results of these simulations on AEZ crop suitability and productivity is in preparation (Fischer and van Velthuisen, forthcoming).

Meanwhile, in order to demonstrate possible effects of climate change on potential distribution patterns of some key crops, a limited set of temperature and rainfall sensitivity scenarios were applied as follows:

- Respectively 1°C, 2°C, and 3°C temperature increase uniformly in each month for both minimum and maximum temperatures, and
- Uniformly distributed combined increases of temperature and precipitation of respectively 1°C and +5% monthly precipitation, temperature increase of 2°C and +5% monthly precipitation, 2°C warming combined with +10% change of annual precipitation, and 3°C warming combined with +10% change of annual rainfall distributed proportionally over the twelve months.

Plate 58 presents four small-scale maps of the potential distribution of rain-fed wheat under respectively current climate, +1°C annual temperature, +2°C combined with +5% annual rainfall, and +3°C combined with +10% annual rainfall. The maps show considerable shifts of the potential distribution even when modest changes of temperature or rainfall are applied. Table 49 presents changes in extents of land very suitable, suitable, and moderately suitable for rain-fed wheat, simulated for the selected temperature and rainfall sensitivity scenarios. Table 47 extends the analysis to the three key cereal crops, i.e., wheat, rice and grain-maize.

Table 49 Impact of temperature and rainfall sensitivity tests on crop suitability, expressed as VS+S+MS extents for rain-fed wheat cultivation (% change relative to current climate)

Region	Temperature Increase			Temperature Increase, Rainfall Change			
	+1°C	+2°C	+3°C	+1°C, +5%	+2°C, +5%	+2°C, +10%	+3°C, +10%
North America	10.9	14.6	18.1	14.6	18.8	21.3	25.4
Eastern Europe	4.1	0.1	-5.5	8.0	3.4	7.5	2.9
Northern Europe	10.7	10.8	11.4	11.8	11.9	11.1	12.3
Southern Europe	5.7	8.5	9.4	9.6	12.3	16.4	17.2
Western Europe	0.2	-3.1	-5.6	0.1	-2.7	-3.2	-7.1
Russian Federation	21.4	31.1	39.2	25.5	36.1	40.5	48.6
	12.2	15.5	17.7	15.4	19.1	22.3	24.5
Caribbean	-57.9	94.7	57.9	-68.4	26.3	15.8	-57.9
Central America	-9.3	-39.7	-65.5	-9.0	-36.9	-29.8	-60.7
	-9.4	-39.4	-65.3	-9.1	-36.8	-29.7	-60.7
South America	-13.2	-24.3	-34.0	-14.4	-24.1	-23.8	-32.2
Oceania	-4.5	-6.0	-8.8	-1.1	-0.4	2.1	-2.3
Polynesia	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	-4.5	-5.9	-8.8	-1.1	-0.4	2.1	-2.3
Eastern Africa	-44.7	-63.7	-78.4	-46.1	-65.1	-66.8	-80.6
Middle Africa	-50.3	-76.0	-92.0	-53.3	-76.4	-77.2	-91.7
Northern Africa	4.3	5.7	7.6	23.5	24.2	43.6	46.7
Southern Africa	-24.5	-33.1	-51.7	-8.7	-16.0	-2.3	-29.9
Western Africa	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
	-38.4	-55.1	-68.7	-36.1	-52.4	-50.3	-64.0
Western Asia	28.7	51.6	65.3	47.7	66.3	83.6	106.8
Southeast. Asia	-11.8	-23.0	-51.6	-18.0	-31.2	-39.7	-59.6
South Asia	-8.1	-28.0	-44.9	-7.3	-25.8	-21.0	-33.3
East Asia	15.9	6.6	-0.5	17.2	8.7	10.8	1.5
Central Asia	9.5	7.4	-1.7	29.3	10.7	46.8	41.6
Japan	-3.6	-10.5	-13.7	-8.8	-13.7	-21.3	-25.7
	7.5	-3.0	-13.2	9.1	-2.0	1.7	-8.2
DEVELOPING	-12.5	-24.0	-34.4	-10.8	-22.0	-19.0	-28.5
DEVELOPED	10.7	13.8	16.2	14.0	17.7	20.5	23.0
WORLD TOTAL	3.9	2.8	1.4	6.8	6.0	8.9	7.9

The application of the various temperature and rainfall sensitivity scenarios revealed a modest increase of cultivable rain-fed land for temperature increases up to 2°C on a global scale. With a higher temperature increase alone, extents of cultivable rain-fed land start to decrease. When both temperature and rainfall amounts increase, the extents of cultivable rain-fed land increase steadily. For example, a temperature increase of 3°C paired with a rainfall increase of 10 percent, would lead to about 4 percent more land globally suitable for rain-fed cultivation of wheat, rice, or grain-maize. In the developed countries this increase is even

markedly higher; it exceeds 25 percent. Contrariwise, for developing countries there would be a decrease of 11 percent.

Table 50 Impact of temperature and rainfall sensitivity tests on crop suitability, expressed as VS+S+MS extents for rain-fed wheat, rice, or grain-maize cultivation (% change relative to current climate)

Region	Temperature Increase			Temperature Increase, Rainfall Change			
	+1°C	+2°C	+3°C	+1°C, +5%	+2°C, +5%	+2°C, +10%	+3°C, +10%
North America	12.0	16.1	20.3	16.1	20.9	23.8	28.4
Eastern Europe	5.7	6.0	0.6	9.6	9.3	13.0	10.3
Northern Europe	10.7	10.8	11.5	11.8	11.9	11.1	12.6
Southern Europe	6.3	10.2	12.1	10.6	14.0	18.6	21.3
Western Europe	0.4	-1.6	-2.9	1.1	-1.0	-1.3	-4.3
Russian Federation	21.6	31.5	40.3	25.8	36.6	41.0	49.7
	12.8	17.4	20.2	16.1	21.1	24.3	27.5
Caribbean	-1.4	-1.7	-1.4	-5.6	-3.9	-12.8	-10.0
Central America	-0.3	-4.3	-9.9	-3.4	-6.9	-8.5	-14.1
	-0.5	-3.9	-8.5	-3.7	-6.4	-9.2	-13.4
South America	-4.4	-11.4	-19.8	-6.9	-12.9	-13.9	-22.7
Oceania	-4.3	-5.3	-9.0	1.0	0.0	4.1	0.4
Polynesia	3.7	-9.0	-18.3	-11.0	-10.2	-19.4	-23.8
	-4.1	-4.7	-9.3	0.7	-0.2	3.6	-0.2
Eastern Africa	-4.1	-8.2	-12.3	-5.8	-9.2	-10.9	-14.8
Middle Africa	-2.5	-7.0	-11.2	-7.0	-11.0	-13.7	-17.9
Northern Africa	-1.2	-3.0	-5.2	3.3	1.4	6.1	4.7
Southern Africa	-17.3	-21.5	-30.9	7.9	-4.1	16.9	3.6
Western Africa	-2.2	-8.4	-13.5	-3.4	-7.9	-8.0	-13.4
	-3.5	-7.8	-12.1	-4.2	-8.1	-8.3	-12.6
Western Asia	28.9	51.7	65.2	47.6	66.4	83.4	106.5
Southeast. Asia	-2.7	-4.5	-11.7	-6.5	-9.2	-14.0	-21.2
South Asia	-2.6	-6.8	-13.6	-0.8	-5.3	-3.0	-8.7
East Asia	17.4	18.9	18.6	16.3	18.2	18.3	20.3
Central Asia	13.0	13.9	6.6	31.5	17.3	54.3	51.1
Japan	-3.4	-8.3	-12.9	-8.7	-11.6	-17.2	-22.2
	4.3	2.5	-2.2	4.7	2.4	3.7	0.4
DEVELOPING	-1.3	-5.5	-11.1	-2.1	-6.0	-5.9	-11.1
DEVELOPED	11.1	15.0	17.7	14.8	19.1	22.2	25.3
WORLD TOTAL	3.9	3.1	1.1	5.0	4.6	5.9	4.3

6. CONCLUDING REMARKS

The term AEZ refers to the Agro-Ecological Zones system, developed by the Food and Agriculture Organization of the United Nations (FAO) in collaboration with the International Institute for Applied Systems Analysis (IIASA). The approach enables rational land-use planning on the basis of an inventory of land resources and an evaluation of their biophysical limitations and potentials for plant production relevant in a particular agro-ecological context, for specified management conditions and levels of inputs.

Recent availability of digital global databases of climatic parameters, topography, soil and terrain, and land cover has allowed for revisions and improvements in calculation procedures of AEZ, enabling global coverage. AEZ provides a standardized framework for the characterization of crop-specific limitations of climate, soil and terrain resources in a consistent and empirically founded way. It systematically computes spatial and temporal data on maximum potential and attainable crop yields as well as expected sustainable agricultural production potentials at different specified levels of inputs and management conditions.

In essence, the Global AEZ assessment has provided a comprehensive and spatially explicit database of crop production potential and related factors. The results are a valuable source of information and input to various global and regional applications. The AEZ computations were completed for a range of climatic conditions, including a reference climate (average of period 1961-1990), individual historical years of 1960 to 1996, and scenarios of future climate based on the published outputs of various global climate models. The FAO/UNESCO Digital Soil Map of the World (DSMW) has been made the reference for constructing a land surface database comprising of more than 2.2 million grid-cells at 5-minutes latitude/longitude within a raster of 2160 rows and 4320 columns.

The study confirms that the Earth's land and climate resources are adequate to meet the needs of food and fiber for a world population of 8.9 thousand million, as projected for the year 2050 by the UN medium variant. Despite this hopeful aggregate picture, there are also reasons for profound concerns. Several regions exist, where the rain-fed cultivation potential has already been exhausted, as for example is the case in parts of Asia. Land degradation, if continuing unchecked, may exacerbate regional land scarcities. Concerns for the environment may prevent some resources from being developed for agriculture. Global warming may alter the condition and distribution of land suitable for cropping. In addition, socioeconomic development may infringe on the current agricultural resource base.

On the basis of currently available global soil, terrain and climate data, the AEZ approach estimates that 10.5 thousand million ha, i.e., more than three-quarters of the global land surface (excluding Antarctica), amounting to roughly 13.4 thousand million ha, suffer rather severe constraints for rain-fed cultivation. Some 13 percent is too cold, 27 percent is too dry, 12 percent is too steep, and about 65 percent are constrained by unfavorable soil conditions.

Combining the AEZ results with spatial land cover data, about 237 million hectares of the areas classified as dominantly forest ecosystems were assessed as very suitable or suitable for cultivation. On the other hand, the analysis shows that globally almost 85 percent of forest ecosystems are considered not suitable or at best marginally suitable for crop cultivation.

The application of various temperature and rainfall sensitivity scenarios revealed a modest increase of cultivable rain-fed land for temperature increases up to 2°C on global scale. With a temperature increase alone, extents of cultivable rain-fed land start to decrease. When both temperature and rainfall amounts increase, the extents of cultivable rain-fed land increase steadily. For example, a temperature increase of 3°C paired with a rainfall increase of 10 percent would lead globally to about 4 percent more cultivable rain-fed land. In the

developed countries this increase is even markedly higher; it exceeds 25 percent. On the contrary, for developing countries there would be a decrease of 11 percent.

Beyond the conventional use of AEZ for mapping and quantifying crop production potentials, there are several recent applications where AEZ or outputs from AEZ analysis have been used for environmental and economic assessments:

AEZ and land evaluation for forestry: With an increased emphasis on multiple use forestry, on agro-forestry, on forest as renewable energy source, and on the role of forests in global CO₂ balances, the scope of quantitative land evaluation for forestry is widening. In a recent IIASA study, covering the territory of the Former Soviet Union and China, the AEZ evaluation procedures have been extended for the calculation of potential tree biomass. Three different types of forest resources management and exploitation were assumed. The first type, termed “*conservation forestry*”, aims at nature conservation, bio-diversity preservation and limited selective extraction of individual trees. The second type reflects traditional forestry, with the main management objectives of maximizing quality and quantity of timber production. This type is referred to as “*traditional forestry*”. The third type captures the fully mechanized biofuel and pulpwood production for energy generation and industrial application of pulpwood. This type was termed “*biomass forestry*”.

AEZ and potentials of fodder and grassland: Among the total of 154 land utilization types implemented in Global AEZ, there are 13 types concerned with fodder and grass production (six types of silage maize, alfalfa, and six generic types of grasses and pasture legumes). The methodology also includes crop coefficients for quantifying crop residues (e.g., straw) and byproducts (e.g., bran from cereals or cakes from processing of oilseeds) potentially available for animal feeding. Together these can provide comprehensive information to assessments of livestock potentials as well as of regional biomass potentials for energy uses from crop and grassland sources.

AEZ linkage to economic modeling: The AEZ land productivity assessment conducted within the Land Use Change Project (LUC) at IIASA provides a multifaceted environmental characterization of land with regard to agricultural uses. Key objectives for its development included the compilation of geographically explicit information that could be embedded within an economic model, to provide a biophysical basis for the estimation of spatially explicit agricultural production relations, and to allow consistent linkage to the modeling of the water sector, in particular the demand for irrigation water. Agricultural production in this economic model is co-determined by the biophysical potential of land, and by the level of factor inputs (in terms of nutrients and power). Potential output is based on results generated by the AEZ model. The rationale behind this specification is that the observed actual crop output level represents a certain fraction of the biophysical potential. The results obtained in LUC's study on China, strongly support the view that it is both possible and worthwhile to integrate information from biophysical/biological process models within an economic model.

AEZ and land-use planning: As an extension of basic land productivity assessments, FAO and IIASA have developed AEZWIN, an MS Windows application for use in national and sub-national resource planning. When evaluating the performance of alternative land utilization types, often the specification of a single objective function does not adequately reflect the preferences of decision-makers, which are of a multi-objective nature in many practical problems dealing with resources. Therefore interactive multi-criteria model analysis has been introduced and applied to the analysis of AEZ models. It is at this level of analysis that socioeconomic considerations can effectively be taken into account.

Limitations

The Global AEZ results presented are based on a half-degree latitude/longitude world climate data set, 5-minutes soils data derived from the digital version of the FAO Soil Map of the World, the 30 arc-seconds latitude/longitude Global Land Cover Characteristics Database, and a 30 arc-second digital elevation data set. While representing the most recent global data compilations, the quality and reliability of these data sets is known to be uneven across regions. Especially the quality of the world soil map is reason for concern. It is based on a 1:5,000,000 scale map and it is generally accepted that its reliability may vary considerably between different areas. At present substantial improvements to the soil information is in progress, as for example, the recent SOTER updates for South America and the Caribbean, North and Central Eurasia, Northeast Africa, and Eastern Europe.

Another issue is that the current status of land degradation cannot be inferred from the FAO Soil Map of the World. The only study available with global coverage, the Global Assessment of Soil Degradation (GLASOD), compiled by ISRIC and UNEP, indicates that state and rate of various types of degradation might very well affect land productivity. However, the GLASOD study itself offers insufficient detail and quantification for useful application within Global AEZ.

Also the agronomic data, such as the data on environmental requirements for some crops, contain generalizations necessary for global applications. In particular assumptions on occurrence and severity of some agro-climate related constraints to crop production would, no doubt, benefit from additional verification and data.

For the above reasons, the results obtained from this Global AEZ study should be treated in a conservative manner at appropriate aggregation levels, which are commensurate with the resolution of basic data and the scale of the study. While various modes have been pursued for “ground-truthing” and verifying results of the Global AEZ suitability analysis, there is a need for further validation of results and underlying databases.

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APPENDIX I

TABLES WITH SELECTED RESULTS OF THE GLOBAL AEZ ASSESSMENT

Table A1	Climate, soil and terrain constraints for rain-fed crop production - North America
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Table A39	Gross extents with cultivation potential for rain-fed plus irrigated sugar crops – intermediate input level.
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Table A42	Gross extents with cultivation potential for rain-fed plus irrigated roots and tubers – high input level.
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- Table A45 Gross extents with cultivation potential for rain-fed plus irrigated sugar crops – high input level.
- Table A46 Gross extents with cultivation potential for rain-fed plus irrigated cotton – high input level.

Table A1 Climate, soil and terrain constraints to rain-fed crop production - North America

Constraints			LGP 0 days CC	LGP 1-60 CC	LGP 60-119 C	LGP 120-179	LGP 180-269	LGP 270-365	LGP 365+ C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		85843	178257	107678	42028	289899	143876	0	847581	39.6
	LGP _{t=5} < 180	C	294	26592	33300	464046	0	0	0	524232	24.5
	LGP _{t=5} < 120	CC	265685	127990	373009	0	0	0	0	766684	35.9
Terrain slopes	0 - 8%		229014	151159	273967	310692	164875	94003	0	1223710	57.2
	8 - 16%	C	55155	70954	73524	76499	62474	32171	0	370777	17.3
	16 - 30%	C	45370	69323	84634	66593	42420	12765	0	321105	15.0
	> 30%	CC	22282	41404	81861	52290	20130	4938	0	222905	10.4
Soil depth	Deep		133360	263190	397512	421637	246856	137949	0	1600504	74.8
	Medium	C	0	4621	430	1193	507	1	0	6752	0.3
	Shallow	CC	22711	53722	90806	58291	18377	3845	0	247752	11.6
Soil fertility	High		78442	174436	152483	91240	113828	20876	0	631305	29.5
	Medium	C	1794	8085	63241	64594	84450	77849	0	300013	14.0
	Low	CC	75834	139012	273023	325287	67462	43070	0	923688	43.2
Soil drainage	Good		155509	305345	428164	425058	215240	113171	0	1642487	76.8
	Poor	CC	562	16188	60583	56063	50501	28624	0	212521	9.9
Soil texture	Medium/fine		67393	176282	263007	313121	214099	118356	0	1152258	53.9
	Sandy/stony	CC	58092	46092	31858	15425	6869	7031	0	165367	7.7
	Cracking clay	C	30585	99160	193882	152574	44773	16409	0	537383	25.1
Soil chemical constraints	None		154715	313967	485112	477123	264714	140398	0	1836029	85.9
	S/S/G*	CC	1356	7566	3635	3997	1027	1397	0	18978	0.9
Miscellaneous land units		CC	195752	11307	25239	24954	24158	2081	0	283491	13.3
Total <i>without</i> constraints			0	0	0	15095	60007	10804	0	85906	4.0
Total with <i>moderate</i> constraints		C	0	0	80090	59320	73411	65086	0	277907	13.0
Total with <i>severe</i> constraints		CC	351822	332840	433896	431660	156480	67986	0	1774684	83.0
Total	(1000 ha)		351822	332840	513986	506075	289899	143876	0	2138498	100.0
	(%)		16.5	15.6	24.0	23.7	13.6	6.7	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A2 Climate, soil and terrain constraints to rain-fed crop production - Eastern Europe

Constraints			LGP 0 days CC	LGP 1-60 CC	LGP 60-119 C	LGP 120-179	LGP 180-269	LGP 270-365	LGP 365+ C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		0	0	16130	29022	124968	0	0	170120	99.5
	LGP _{t=5} < 180	C	0	0	0	834	0	0	0	834	0.5
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		0	0	8782	12144	74557	0	0	95483	55.9
	8 - 16%	C	0	0	5419	9335	23679	0	0	38433	22.5
	16 - 30%	C	0	0	1903	6269	18744	0	0	26916	15.7
	> 30%	CC	0	0	26	2107	7987	0	0	10120	5.9
Soil depth	Deep		0	0	15485	27932	119933	0	0	163350	95.6
	Medium	C	0	0	0	0	0	0	0	0	0.0
	Shallow	CC	0	0	92	1638	4615	0	0	6345	3.7
Soil fertility	High		0	0	14794	22922	45729	0	0	83445	48.8
	Medium	C	0	0	478	4593	61903	0	0	66974	39.2
	Low	CC	0	0	305	2054	16915	0	0	19274	11.3
Soil drainage	Good		0	0	14879	27733	97488	0	0	140100	82.0
	Poor	CC	0	0	698	1837	27059	0	0	29594	17.3
Soil texture	Medium/fine		0	0	15189	25083	84144	0	0	124416	72.8
	Sandy/stony	CC	0	0	191	1782	3154	0	0	5127	3.0
	Cracking clay	C	0	0	197	2705	37250	0	0	40152	23.5
Soil chemical constraints	None		0	0	8025	25644	120287	0	0	153956	90.1
	S/S/G*	CC	0	0	7552	3926	4260	0	0	15738	9.2
Miscellaneous land units		CC	0	0	553	286	420	0	0	1259	0.7
Total <i>without</i> constraints			0	0	0	11610	24193	0	0	35803	20.9
Total with <i>moderate</i> constraints		C	0	0	7112	8758	51254	0	0	67124	39.3
Total with <i>severe</i> constraints		CC	0	0	9018	9488	49521	0	0	68027	39.8
Total	(1000 ha)		0	0	16130	29856	124968	0	0	170954	100.0
	(%)		0.0	0.0	9.4	17.5	73.1	0.0	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A3 Climate, soil and terrain constraints to rain-fed crop production - Northern Europe

Constraints			LGP 0 days CC	LGP 1-60 CC	LGP 60-119 C	LGP 120-179	LGP 180-269	LGP 270-365	LGP 365+ C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		0	0	0	0	57982	12025	0	70007	40.6
	LGP _{t=5} < 180	C	0	0	0	71432	0	0	0	71432	41.4
	LGP _{t=5} < 120	CC	0	649	30436	0	0	0	0	31085	18.0
Terrain slopes	0 - 8%		0	156	6307	28238	37882	7409	0	79992	46.4
	8 - 16%	C	0	185	7165	19481	11372	2646	0	40849	23.7
	16 - 30%	C	0	185	9950	16203	6652	1696	0	34686	20.1
	> 30%	CC	0	122	7014	7510	2076	275	0	16997	9.9
Soil depth	Deep		0	135	20282	59822	50735	11612	0	142586	82.6
	Medium	C	0	0	0	0	0	0	0	0	0.0
	Shallow	CC	0	148	9049	7823	5413	312	0	22745	13.2
Soil fertility	High		0	55	3168	3498	17279	4163	0	28163	16.3
	Medium	C	0	0	689	5234	21132	5985	0	33040	19.2
	Low	CC	0	229	25474	58913	17737	1777	0	104130	60.4
Soil drainage	Good		0	283	29332	66788	44842	7990	0	149235	86.5
	Poor	CC	0	0	0	857	11306	3934	0	16097	9.3
Soil texture	Medium/fine		0	115	11125	35175	38405	10624	0	95444	55.3
	Sandy/stony	CC	0	87	5186	1506	1178	63	0	8020	4.6
	Cracking clay	C	0	81	13021	30965	16565	1237	0	61869	35.9
Soil chemical constraints	None		0	283	29332	67645	56148	11924	0	165332	95.8
	S/S/G*	CC	0	0	0	0	0	0	0	0	0.0
Miscellaneous land units		CC	0	366	1105	3787	1834	102	0	7194	4.2
Total <i>without</i> constraints			0	0	0	0	5500	2067	0	7567	4.4
Total with <i>moderate</i> constraints		C	0	0	0	6544	19053	3858	0	29455	17.1
Total with <i>severe</i> constraints		CC	0	649	30436	64888	33429	6100	0	135502	78.5
Total	(1000 ha)		0	649	30436	71432	57982	12025	0	172524	100.0
	(%)		0.0	0.4	17.6	41.4	33.6	7.0	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A4 Climate, soil and terrain constraints to rain-fed crop production - Southern Europe

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		150	0	429	31295	81247	15374	0	128495	97.6
	LGP _{t=5} < 180	C	0	0	0	2267	0	0	0	2267	1.7
	LGP _{t=5} < 120	CC	0	47	832	0	0	0	0	879	0.7
Terrain slopes	0 - 8%		48	0	76	5341	15787	4133	0	25385	19.3
	8 - 16%	C	35	0	79	6722	14325	2184	0	23345	17.7
	16 - 30%	C	57	3	189	10961	26007	4907	0	42124	32.0
	> 30%	CC	10	44	917	10537	25128	4151	0	40787	31.0
Soil depth	Deep		101	0	572	23531	59162	10882	0	94248	71.6
	Medium	C	36	0	0	1147	550	51	0	1784	1.4
	Shallow	CC	13	12	630	8656	21445	4372	0	35128	26.7
Soil fertility	High		65	0	393	18935	37658	6581	0	63632	48.3
	Medium	C	48	0	107	7392	24997	5569	0	38113	29.0
	Low	CC	38	12	702	7006	18503	3155	0	29416	22.3
Soil drainage	Good		150	12	1202	32435	75658	14627	0	124084	94.3
	Poor	CC	0	0	0	899	5500	679	0	7078	5.4
Soil texture	Medium/fine		110	9	704	20543	54493	9849	0	85708	65.1
	Sandy/stony	CC	25	0	49	2605	6156	1028	0	9863	7.5
	Cracking clay	C	15	3	450	10186	20509	4429	0	35592	27.0
Soil chemical constraints	None		150	12	1202	31637	78180	15114	0	126295	95.9
	S/S/G*	CC	0	0	0	1697	2978	191	0	4866	3.7
Miscellaneous land units		CC	0	35	59	228	90	69	0	481	0.4
Total <i>without</i> constraints			0	0	0	4555	11121	2116	0	17792	13.5
Total with <i>moderate</i> constraints		C	0	0	269	13997	29878	6117	0	50261	38.2
Total with <i>severe</i> constraints		CC	150	47	992	15010	40248	7142	0	63589	48.3
Total	(1000 ha)		150	47	1261	33562	81247	15374	0	131641	100.0
	(%)		0.1	0.0	1.0	25.5	61.7	11.7	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A5 Climate, soil and terrain constraints to rain-fed crop production - Western Europe

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		0	0	0	0	89637	14339	0	103976	94.9
	LGP _{t=5} < 180	C	0	0	0	4965	0	0	0	4965	4.5
	LGP _{t=5} < 120	CC	0	164	442	0	0	0	0	606	0.6
Terrain slopes	0 - 8%		0	0	1	41	38374	6930	0	45346	41.4
	8 - 16%	C	0	1	2	64	21387	4654	0	26108	23.8
	16 - 30%	C	0	9	22	399	20684	2206	0	23320	21.3
	> 30%	CC	0	154	417	4461	9192	550	0	14774	13.5
Soil depth	Deep		0	4	70	2008	74223	13275	0	89580	81.8
	Medium	C	0	0	0	0	0	0	0	0	0.0
	Shallow	CC	0	154	295	2808	14616	1046	0	18919	17.3
Soil fertility	High		0	0	8	948	36255	7000	0	44211	40.4
	Medium	C	0	1	29	1162	32495	3860	0	37547	34.3
	Low	CC	0	157	328	2707	20088	3460	0	26740	24.4
Soil drainage	Good		0	158	365	4686	74309	11955	0	91473	83.5
	Poor	CC	0	0	0	131	14529	2366	0	17026	15.5
Soil texture	Medium/fine		0	115	236	2521	68214	12069	0	83155	75.9
	Sandy/stony	CC	0	0	0	48	1662	30	0	1740	1.6
	Cracking clay	C	0	44	130	2248	18962	2222	0	23606	21.5
Soil chemical constraints	None		0	158	365	4817	88699	14298	0	108337	98.9
	S/S/G*	CC	0	0	0	0	140	24	0	164	0.1
Miscellaneous land units		CC	0	6	77	148	799	18	0	1048	1.0
Total <i>without</i> constraints			0	0	0	0	18327	4543	0	22870	20.9
Total with <i>moderate</i> constraints		C	0	0	0	584	25561	3630	0	29775	27.2
Total with <i>severe</i> constraints		CC	0	164	442	4380	45750	6166	0	56902	51.9
Total	(1000 ha)		0	164	442	4965	89637	14339	0	109547	100.0
	(%)		0.0	0.1	0.4	4.5	81.8	13.1	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A6 Climate, soil and terrain constraints to rain-fed crop production - Russian Federation

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		0	23969	54727	23614	75513	172	0	177995	10.6
	LGP _{t=5} < 180	C	0	7048	54318	688891	0	0	0	750257	44.8
	LGP _{t=5} < 120	CC	4682	47869	693342	0	0	0	0	745893	44.6
Terrain slopes	0 - 8%		468	41124	313047	343433	49107	8	0	747187	44.6
	8 - 16%	C	543	12822	176957	163812	17529	17	0	371680	22.2
	16 - 30%	C	1581	13067	192718	142188	6477	82	0	356113	21.3
	> 30%	CC	2090	11873	119665	63073	2401	64	0	199166	11.9
Soil depth	Deep		837	50012	457678	512632	69657	100	0	1090916	65.2
	Medium	C	0	0	0	64	0	0	0	64	0.0
	Shallow	CC	3691	25490	333146	187526	4852	71	0	554776	33.1
Soil fertility	High		0	20819	85676	92519	21091	56	0	220161	13.2
	Medium	C	0	2221	63900	216818	47326	100	0	330365	19.7
	Low	CC	4528	52463	641249	390885	6092	16	0	1095233	65.4
Soil drainage	Good		3494	57650	614716	567435	61440	172	0	1304907	77.9
	Poor	CC	1034	17852	176108	132787	13070	0	0	340851	20.4
Soil texture	Medium/fine		2783	61365	674167	613615	63311	172	0	1415413	84.5
	Sandy/stony	CC	1745	12217	82941	15893	82	0	0	112878	6.7
	Cracking clay	C	0	1920	33716	70714	11117	0	0	117467	7.0
Soil chemical constraints	None		4528	57108	756127	690871	73584	172	0	1582390	94.5
	S/S/G*	CC	0	18394	34697	9351	926	0	0	63368	3.8
Miscellaneous land units		CC	154	3384	11563	12284	1004	0	0	28389	1.7
Total <i>without</i> constraints			0	0	0	9624	11518	0	0	21142	1.3
Total with <i>moderate</i> constraints		C	0	0	45384	152632	42410	89	0	240515	14.4
Total with <i>severe</i> constraints		CC	4682	78886	757002	550250	21585	83	0	1412488	84.4
Total	(1000 ha)		4682	78886	802387	712506	75513	172	0	1674146	100.0
	(%)		0.3	4.7	47.9	42.6	4.5	0.0	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A7 Climate, soil and terrain constraints to rain-fed crop production - the Caribbean

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		0	0	92	0	7574	15730	0	23396	100.0
	LGP _{t=5} < 180	C	0	0	0	0	0	0	0	0	0.0
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		0	0	65	0	5408	6114	0	11587	49.5
	8 - 16%	C	0	0	20	0	961	2480	0	3461	14.8
	16 - 30%	C	0	0	7	0	721	3926	0	4654	19.9
	> 30%	CC	0	0	0	0	484	3210	0	3694	15.8
Soil depth	Deep		0	0	17	0	5064	10345	0	15426	65.9
	Medium	C	0	0	0	0	0	0	0	0	0.0
	Shallow	CC	0	0	75	0	2478	5081	0	7634	32.6
Soil fertility	High		0	0	17	0	4283	6262	0	10562	45.1
	Medium	C	0	0	0	0	2089	6209	0	8298	35.5
	Low	CC	0	0	75	0	1170	2955	0	4200	18.0
Soil drainage	Good		0	0	92	0	6557	14400	0	21049	90.0
	Poor	CC	0	0	0	0	985	1026	0	2011	8.6
Soil texture	Medium/fine		0	0	92	0	6142	12803	0	19037	81.4
	Sandy/stony	CC	0	0	0	0	1337	2497	0	3834	16.4
	Cracking clay	C	0	0	0	0	63	126	0	189	0.8
Soil chemical constraints	None		0	0	92	0	7330	15230	0	22652	96.8
	S/S/G*	CC	0	0	0	0	212	196	0	408	1.7
Miscellaneous land units		CC	0	0	0	0	32	304	0	336	1.4
Total <i>without</i> constraints			0	0	0	0	449	1345	0	1794	7.7
Total with <i>moderate</i> constraints		C	0	0	17	0	1480	4428	0	5925	25.3
Total with <i>severe</i> constraints		CC	0	0	75	0	5645	9957	0	15677	67.0
Total	(1000 ha)		0	0	92	0	7574	15730	0	23396	100.0
	(%)		0.0	0.0	0.4	0.0	32.4	67.2	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A8 Climate, soil and terrain constraints to rain-fed crop production - Central America

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		55915	22222	26709	29382	54766	58353	1006	248353	100.0
	LGP _{t=5} < 180	C	0	0	0	0	0	0	0	0	0.0
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		21982	8302	6225	4545	14952	23485	239	79730	32.1
	8 - 16%	C	13131	4636	5123	4017	5533	8793	75	41308	16.6
	16 - 30%	C	13048	5470	8557	9008	13107	12716	185	62091	25.0
	> 30%	CC	7754	3814	6804	11813	21175	13358	507	65225	26.3
Soil depth	Deep		26227	12048	12874	20192	35917	44807	768	152833	61.5
	Medium	C	1130	861	594	376	0	0	0	2961	1.2
	Shallow	CC	28370	9042	13225	8605	18052	12889	238	90421	36.4
Soil fertility	High		44947	16873	17872	14671	26965	18362	200	139890	56.3
	Medium	C	358	742	1808	6514	15601	25800	612	51435	20.7
	Low	CC	10421	4335	7013	7988	11403	13534	194	54888	22.1
Soil drainage	Good		55703	21311	26094	28673	51246	50698	844	234569	94.4
	Poor	CC	24	639	599	500	2722	6998	162	11644	4.7
Soil texture	Medium/fine		45467	19084	24560	21724	38203	49636	917	199591	80.4
	Sandy/stony	CC	6418	2683	1566	5265	11881	6878	74	34765	14.0
	Cracking clay	C	3842	184	567	2184	3884	1182	15	11858	4.8
Soil chemical constraints	None		54108	21798	26554	29090	53379	57136	1004	243069	97.9
	S/S/G*	CC	1619	153	140	84	589	560	2	3147	1.3
Miscellaneous land units		CC	189	271	15	209	798	657	0	2139	0.9
Total <i>without</i> constraints			0	0	0	5243	7098	4872	0	17213	6.9
Total with <i>moderate</i> constraints		C	0	0	10543	6389	10655	18358	371	46316	18.6
Total with <i>severe</i> constraints		CC	55915	22222	16166	17750	37014	35122	635	184824	74.4
Total	(1000 ha)		55915	22222	26709	29382	54766	58353	1006	248353	100.0
	(%)		22.5	8.9	10.8	11.8	22.1	23.5	0.4	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A9 Climate, soil and terrain constraints to rain-fed crop production - South America

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		118920	54806	92024	128820	379752	858595	118565	1751482	98.5
	LGP _{t=5} < 180	C	6375	2783	3874	3478	0	0	0	16510	0.9
	LGP _{t=5} < 120	CC	7268	1997	316	0	0	0	0	9581	0.5
Terrain slopes	0 - 8%		44747	25599	39234	72395	265661	629789	98085	1175510	66.1
	8 - 16%	C	26573	11538	13425	21223	59658	119619	9262	261298	14.7
	16 - 30%	C	32285	11374	18959	20344	38163	79920	7262	208307	11.7
	> 30%	CC	28957	11076	24596	18336	16269	29267	3955	132456	7.5
Soil depth	Deep		98497	44883	70455	104351	344340	806230	112792	1581548	89.0
	Medium	C	2966	2929	3464	2653	2977	2183	0	17172	1.0
	Shallow	CC	26029	10023	18979	22126	29348	37191	4274	147970	8.3
Soil fertility	High		75772	35802	44898	40905	51187	113182	5244	366990	20.6
	Medium	C	9348	5000	15069	40512	115899	282057	38599	506484	28.5
	Low	CC	42372	17033	32930	47714	209579	450366	73222	873216	49.1
Soil drainage	Good		126147	57410	89156	120592	331505	741707	97199	1563716	88.0
	Poor	CC	1345	425	3742	8539	45160	103898	19867	182976	10.3
Soil texture	Medium/fine		92136	41268	67103	94745	290028	746127	112765	1444172	81.2
	Sandy/stony	CC	14857	5266	8310	7911	9938	21525	439	68246	3.8
	Cracking clay	C	20500	11301	17485	26475	76699	77953	3863	234276	13.2
Soil chemical constraints	None		108672	48611	74797	106444	354929	829062	116699	1639214	92.2
	S/S/G*	CC	18821	9223	18101	22686	21736	16543	367	107477	6.0
Miscellaneous land units		CC	5071	1751	3317	3167	3088	12990	1499	30883	1.7
Total <i>without</i> constraints			0	0	0	12457	19682	48002	0	80141	4.5
Total with <i>moderate</i> constraints		C	0	0	37587	41635	96234	239377	30821	445654	25.1
Total with <i>severe</i> constraints		CC	132563	59586	58627	78206	263837	571215	87744	1251778	70.4
Total	(1000 ha)		132563	59586	96214	132298	379752	858595	118565	1777573	100.0
	(%)		7.5	3.4	5.4	7.4	21.4	48.3	6.7	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A10 Climate, soil and terrain constraints to rain-fed crop production - Oceania

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		398936	89839	126118	73949	50218	52283	1203	792546	99.9
	LGP _{t=5} < 180	C	0	0	0	882	0	0	0	882	0.1
	LGP _{t=5} < 120	CC	111	0	0	0	0	0	0	111	0.0
Terrain slopes	0 - 8%		385892	87425	115622	65126	27912	16469	178	698624	88.0
	8 - 16%	C	11050	2034	8743	7042	9256	13092	280	51497	6.5
	16 - 30%	C	1979	366	1639	1716	7036	15910	473	29119	3.7
	> 30%	CC	126	14	115	947	6015	6813	272	14302	1.8
Soil depth	Deep		293420	68024	95757	61563	41284	47226	1142	608416	76.7
	Medium	C	65290	14978	10359	3332	1568	84	0	95611	12.0
	Shallow	CC	33126	5950	19219	9695	7039	4523	60	79612	10.0
Soil fertility	High		199215	41879	53018	25401	11994	10375	135	342017	43.1
	Medium	C	74968	23922	27624	19599	21133	25507	711	193464	24.4
	Low	CC	117653	23152	44692	29591	16764	15951	357	248160	31.3
Soil drainage	Good		378450	83845	112644	62924	40379	41886	1177	721305	90.9
	Poor	CC	13386	5107	12690	11667	9512	9947	26	62335	7.9
Soil texture	Medium/fine		182570	37340	54634	34307	28339	34337	744	372271	46.9
	Sandy/stony	CC	77606	19028	30330	15034	6584	4775	0	153357	19.3
	Cracking clay	C	131659	32585	40371	25250	14968	12721	459	258013	32.5
Soil chemical constraints	None		315089	75418	99871	54835	39639	45312	1203	631367	79.6
	S/S/G*	CC	76747	13535	25463	19755	10252	6521	0	152273	19.2
Miscellaneous land units		CC	7212	887	784	240	328	450	0	9901	1.2
Total <i>without</i> constraints			0	0	0	8121	4307	5302	0	17730	2.2
Total with <i>moderate</i> constraints		C	0	0	36872	9452	12493	17530	719	77066	9.7
Total with <i>severe</i> constraints		CC	399047	89839	89246	57259	33419	29451	484	698745	88.1
Total	(1000 ha)		399047	89839	126118	74831	50218	52283	1203	793539	100.0
	(%)		50.3	11.3	15.9	9.4	6.3	6.6	0.2	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A11 Climate, soil and terrain constraints to rain-fed crop production - Polynesia

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		0	0	0	0	2252	22107	31330	55689	99.2
	LGP _{t=5} < 180	C	0	0	0	0	0	0	0	0	0.0
	LGP _{t=5} < 120	CC	428	0	0	0	0	0	0	428	0.8
Terrain slopes	0 - 8%		71	0	0	0	930	9299	10428	20728	36.9
	8 - 16%	C	106	0	0	0	270	2818	4755	7949	14.2
	16 - 30%	C	148	0	0	0	602	4538	8169	13457	24.0
	> 30%	CC	103	0	0	0	451	5451	7978	13983	24.9
Soil depth	Deep		416	0	0	0	1758	19049	26383	47606	84.8
	Medium	C	0	0	0	0	0	0	0	0	0.0
	Shallow	CC	12	0	0	0	494	2685	4863	8054	14.4
Soil fertility	High		124	0	0	0	645	3652	7165	11586	20.6
	Medium	C	271	0	0	0	575	10020	16174	27040	48.2
	Low	CC	33	0	0	0	1032	8063	7906	17034	30.4
Soil drainage	Good		428	0	0	0	2139	19524	28943	51034	90.9
	Poor	CC	0	0	0	0	113	2211	2302	4626	8.2
Soil texture	Medium/fine		214	0	0	0	2008	19779	27875	49876	88.9
	Sandy/stony	CC	10	0	0	0	93	1262	2235	3600	6.4
	Cracking clay	C	204	0	0	0	152	694	1136	2186	3.9
Soil chemical constraints	None		428	0	0	0	2223	21530	31035	55216	98.4
	S/S/G*	CC	0	0	0	0	30	205	211	446	0.8
Miscellaneous land units		CC	0	0	0	0	0	372	85	457	0.8
Total <i>without</i> constraints			0	0	0	0	366	873	0	1239	2.2
Total with <i>moderate</i> constraints		C	0	0	0	0	546	7820	14084	22450	40.0
Total with <i>severe</i> constraints		CC	428	0	0	0	1340	13414	17246	32428	57.8
Total	(1000 ha)		428	0	0	0	2252	22107	31330	56117	100.0
	(%)		0.8	0.0	0.0	0.0	4.0	39.4	55.8	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A12 Climate, soil and terrain constraints to rain-fed crop production - Eastern Africa

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		72049	46225	72046	149284	230233	69637	0	639474	100.0
	LGP _{t=5} < 180	C	0	0	0	0	0	0	0	0	0.0
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		37021	24615	35803	59655	102247	21617	0	280958	43.9
	8 - 16%	C	14799	11548	16417	38638	56443	15650	0	153495	24.0
	16 - 30%	C	12178	7035	12352	35996	51112	21086	0	139759	21.9
	> 30%	CC	8050	3027	7473	14995	20431	11284	0	65260	10.2
Soil depth	Deep		42073	32586	52157	129313	199546	57293	0	512968	80.2
	Medium	C	13639	991	954	1050	1022	428	0	18084	2.8
	Shallow	CC	14125	12385	18852	17489	21799	5089	0	89739	14.0
Soil fertility	High		35831	27867	38228	38458	54810	14341	0	209535	32.8
	Medium	C	7182	7649	22105	63435	86830	23745	0	210946	33.0
	Low	CC	26823	10446	11629	45959	80728	24723	0	200308	31.3
Soil drainage	Good		68163	45493	70790	138300	206550	59115	0	588411	92.0
	Poor	CC	1674	469	1173	9551	15818	3695	0	32380	5.1
Soil texture	Medium/fine		49859	30021	44046	96324	154365	53720	0	428335	67.0
	Sandy/stony	CC	13710	11275	18578	13026	21548	4730	0	82867	13.0
	Cracking clay	C	6267	4665	9340	38501	46455	4360	0	109588	17.1
Soil chemical constraints	None		59537	38222	65813	142453	219413	62533	0	587971	91.9
	S/S/G*	CC	10299	7739	6149	5399	2954	277	0	32817	5.1
Miscellaneous land units		CC	2212	264	83	1432	7865	6827	0	18683	2.9
Total <i>without</i> constraints			0	0	0	12068	15673	4884	0	32625	5.1
Total with <i>moderate</i> constraints		C	0	0	35404	62301	82314	22119	0	202138	31.6
Total with <i>severe</i> constraints		CC	72049	46225	36642	74915	132246	42634	0	404711	63.3
Total	(1000 ha)		72049	46225	72046	149284	230233	69637	0	639474	100.0
	(%)		11.3	7.2	11.3	23.3	36.0	10.9	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A13 Climate, soil and terrain constraints to rain-fed crop production - Middle Africa

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		63174	22958	23073	58319	200583	287412	1543	657062	100.0
	LGP _{t=5} < 180	C	0	0	0	0	0	0	0	0	0.0
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		41498	14710	14970	41655	88472	217745	1539	420589	64.0
	8 - 16%	C	9439	4730	5190	10224	44455	38826	4	112868	17.2
	16 - 30%	C	8117	2715	2081	5109	58217	25927	0	102166	15.5
	> 30%	CC	4120	804	833	1331	9438	4914	0	21440	3.3
Soil depth	Deep		26639	18718	19104	52734	192080	278017	1543	588835	89.6
	Medium	C	0	0	962	3316	740	1421	0	6439	1.0
	Shallow	CC	17988	2349	2158	2086	6119	5003	0	35703	5.4
Soil fertility	High		22409	3028	6043	18969	22350	16867	207	89873	13.7
	Medium	C	3682	12885	11156	28139	62331	89322	153	207668	31.6
	Low	CC	18535	5154	5026	11028	114258	178251	1183	333435	50.7
Soil drainage	Good		44582	20499	18869	46753	182809	234459	1198	549169	83.6
	Poor	CC	44	568	3356	11383	16131	49982	344	81808	12.5
Soil texture	Medium/fine		16611	7966	11348	27199	115096	192443	1482	372145	56.6
	Sandy/stony	CC	3690	2154	4314	10394	13096	6019	0	39667	6.0
	Cracking clay	C	24325	10947	6563	20542	70747	85979	61	219164	33.4
Soil chemical constraints	None		44050	17810	17436	55713	198678	283916	1543	619146	94.2
	S/S/G*	CC	576	3257	4789	2423	261	525	0	11831	1.8
Miscellaneous land units		CC	18547	1891	848	183	1643	2971	0	26083	4.0
Total <i>without</i> constraints			0	0	0	2279	2854	3332	0	8465	1.3
Total with <i>moderate</i> constraints		C	0	0	9158	22857	54865	46642	72	133594	20.3
Total with <i>severe</i> constraints		CC	63174	22958	13915	33183	142864	237438	1471	515003	78.4
Total	(1000 ha)		63174	22958	23073	58319	200583	287412	1543	657062	100.0
	(%)		9.6	3.5	3.5	8.9	30.5	43.7	0.2	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A14 Climate, soil and terrain constraints to rain-fed crop production - Northern Africa

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		575390	39201	57499	57802	62990	1230	0	794112	100.0
	LGP _{t=5} < 180	C	0	0	0	0	0	0	0	0	0.0
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		354543	23024	29047	31730	37497	388	0	476229	60.0
	8 - 16%	C	126105	9763	14183	11211	10199	457	0	171918	21.6
	16 - 30%	C	74347	4535	8446	9275	7571	355	0	104529	13.2
	> 30%	CC	20395	1879	5823	5586	7723	31	0	41437	5.2
Soil depth	Deep		321109	31806	42331	45388	51547	1188	0	493369	62.1
	Medium	C	9159	1052	4476	5511	4012	0	0	24210	3.0
	Shallow	CC	94151	5815	10361	6711	7417	42	0	124497	15.7
Soil fertility	High		301322	21935	33476	34764	25401	34	0	416932	52.5
	Medium	C	2874	9078	12944	14492	20049	158	0	59595	7.5
	Low	CC	120223	7659	10748	8353	17527	1038	0	165548	20.8
Soil drainage	Good		421900	37407	55773	52911	54644	1184	0	623819	78.6
	Poor	CC	2518	1265	1395	4699	8333	46	0	18256	2.3
Soil texture	Medium/fine		169613	14952	28695	32380	36672	1019	0	283331	35.7
	Sandy/stony	CC	73471	9781	14004	17528	20651	99	0	135534	17.1
	Cracking clay	C	181334	13939	14469	7703	5654	113	0	223212	28.1
Soil chemical constraints	None		402787	35291	54656	55678	62302	1230	0	611944	77.1
	S/S/G*	CC	21631	3381	2512	1932	675	0	0	30131	3.8
Miscellaneous land units		CC	150972	529	331	192	14	0	0	152038	19.1
Total <i>without</i> constraints			0	0	0	7130	4162	20	0	11312	1.4
Total with <i>moderate</i> constraints		C	0	0	28450	17118	9047	28	0	54643	6.9
Total with <i>severe</i> constraints		CC	575390	39201	29048	33554	49781	1182	0	728156	91.7
Total	(1000 ha)		575390	39201	57499	57802	62990	1230	0	794112	100.0
	(%)		72.5	4.9	7.2	7.3	7.9	0.2	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A15 Climate, soil and terrain constraints to rain-fed crop production - Southern Africa

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		104711	46827	64047	23896	22454	4493	0	266428	100.0
	LGP _{t=5} < 180	C	0	0	0	0	0	0	0	0	0.0
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		45219	23364	38202	4990	985	405	0	113165	42.5
	8 - 16%	C	28089	10195	13405	4370	2316	465	0	58840	22.1
	16 - 30%	C	21574	8310	8405	8146	8395	1337	0	56167	21.1
	> 30%	CC	9829	4958	4034	6390	10758	2285	0	38254	14.4
Soil depth	Deep		87091	38459	56201	20066	18958	3820	0	224595	84.3
	Medium	C	1272	95	1862	0	0	0	0	3229	1.2
	Shallow	CC	12843	6320	4531	3784	3413	612	0	31503	11.8
Soil fertility	High		45139	14785	20292	5744	8325	1180	0	95465	35.8
	Medium	C	25871	17256	25476	11743	8852	1783	0	90981	34.1
	Low	CC	30197	12834	16826	6362	5194	1469	0	72882	27.4
Soil drainage	Good		101044	44313	55675	21876	21221	4409	0	248538	93.3
	Poor	CC	162	561	6918	1973	1150	23	0	10787	4.0
Soil texture	Medium/fine		41280	21520	27005	14744	16927	3384	0	124860	46.9
	Sandy/stony	CC	7039	3347	7849	2257	2893	48	0	23433	8.8
	Cracking clay	C	52887	20007	27740	6849	2551	1000	0	111034	41.7
Soil chemical constraints	None		97442	41334	53256	22333	21563	4064	0	239992	90.1
	S/S/G*	CC	3765	3540	9338	1516	808	368	0	19335	7.3
Miscellaneous land units		CC	3505	1953	1453	47	83	61	0	7102	2.7
Total <i>without</i> constraints			0	0	0	2238	3204	648	0	6090	2.3
Total with <i>moderate</i> constraints		C	0	0	30287	10329	7446	1674	0	49736	18.7
Total with <i>severe</i> constraints		CC	104711	46827	33760	11329	11804	2171	0	210602	79.0
Total	(1000 ha)		104711	46827	64047	23896	22454	4493	0	266428	100.0
	(%)		39.3	17.6	24.0	9.0	8.4	1.7	0.0	100.0	

* Salinity/Sodicity/Gypsum

C: Moderate or slight constraint

CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A16 Climate, soil and terrain constraints to rain-fed crop production - Western Africa

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		276409	45835	65798	77894	111616	55443	0	632995	100.0
	LGP _{t=5} < 180	C	0	0	0	0	0	0	0	0	0.0
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		252377	35742	50589	49527	72732	42067	0	503034	79.5
	8 - 16%	C	16462	8032	12759	20569	22043	8701	0	88566	14.0
	16 - 30%	C	6868	1847	2351	7003	14403	4061	0	36533	5.8
	> 30%	CC	702	214	99	795	2437	614	0	4861	0.8
Soil depth	Deep		137649	38386	56680	53638	83792	48568	0	418713	66.1
	Medium	C	712	1063	3499	6420	7441	2006	0	21141	3.3
	Shallow	CC	34131	2384	4746	17677	19543	3574	0	82055	13.0
Soil fertility	High		111224	11750	18721	18429	11194	4626	0	175944	27.8
	Medium	C	23611	26691	39959	43678	59828	24357	0	218124	34.5
	Low	CC	37657	3393	6244	15628	39754	25164	0	127840	20.2
Soil drainage	Good		171001	37747	57732	67770	100269	48998	0	483517	76.4
	Poor	CC	1491	4087	7192	9964	10508	5150	0	38392	6.1
Soil texture	Medium/fine		51937	8070	18028	39097	74797	37956	0	229885	36.3
	Sandy/stony	CC	14415	4312	8435	10142	3491	423	0	41218	6.5
	Cracking clay	C	106140	29452	38460	28495	32487	15769	0	250803	39.6
Soil chemical constraints	None		170666	38784	59727	75839	109364	52660	0	507040	80.1
	S/S/G*	CC	1826	3050	5197	1896	1412	1488	0	14869	2.3
Miscellaneous land units		CC	103917	4001	874	159	839	1295	0	111085	17.5
Total <i>without</i> constraints			0	0	0	1369	4412	2195	0	7976	1.3
Total with <i>moderate</i> constraints		C	0	0	42616	37864	53973	21414	0	155867	24.6
Total with <i>severe</i> constraints		CC	276409	45835	23182	38660	53231	31834	0	469151	74.1
Total	(1000 ha)		276409	45835	65798	77894	111616	55443	0	632995	100.0
	(%)		43.7	7.2	10.4	12.3	17.6	8.8	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A17 Climate, soil and terrain constraints to rain-fed crop production - Western Asia

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		314486	7968	48226	44420	16610	239	0	431949	99.8
	LGP _{t=5} < 180	C	0	0	702	341	0	0	0	1043	0.2
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		136158	5374	11246	7010	2421	86	0	162295	37.5
	8 - 16%	C	83098	1500	9103	8181	2451	17	0	104350	24.1
	16 - 30%	C	61218	585	14422	13988	5082	62	0	95357	22.0
	> 30%	CC	34012	509	14157	15583	6657	73	0	70991	16.4
Soil depth	Deep		171147	5574	28037	28128	10701	203	0	243790	56.3
	Medium	C	15041	1221	3610	1647	36	0	0	21555	5.0
	Shallow	CC	94221	1122	16481	14729	5781	36	0	132370	30.6
Soil fertility	High		172143	3523	31448	26698	8608	16	0	242436	56.0
	Medium	C	24693	197	1914	7812	4323	203	0	39142	9.0
	Low	CC	83572	4197	14766	9994	3586	20	0	116135	26.8
Soil drainage	Good		278945	7654	47430	44228	15929	239	0	394425	91.1
	Poor	CC	1463	263	697	276	588	0	0	3287	0.8
Soil texture	Medium/fine		131224	6213	33639	31828	11030	226	0	214160	49.5
	Sandy/stony	CC	16568	471	4196	4344	1656	0	0	27235	6.3
	Cracking clay	C	132616	1234	10293	8332	3831	13	0	156319	36.1
Soil chemical constraints	None		263079	5578	46118	43986	16369	239	0	375369	86.7
	S/S/G*	CC	17329	2340	2010	518	149	0	0	22346	5.2
Miscellaneous land units		CC	34078	50	800	258	93	0	0	35279	8.1
Total <i>without</i> constraints			0	0	0	9926	2209	0	0	12135	2.8
Total with <i>moderate</i> constraints		C	0	0	20583	12090	5418	191	0	38282	8.8
Total with <i>severe</i> constraints		CC	314486	7968	28345	22745	8984	48	0	382576	88.4
Total	(1000 ha)		314486	7968	48928	44761	16610	239	0	432992	100.0
	(%)		72.6	1.8	11.3	10.3	3.8	0.1	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A18 Climate, soil and terrain constraints to rain-fed crop production - Southeast Asia

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		0	0	0	0	114847	217371	112001	444219	99.9
	LGP _{t=5} < 180	C	0	0	0	264	0	0	0	264	0.1
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		0	0	0	3	54549	83865	50042	188459	42.4
	8 - 16%	C	0	0	0	9	17955	26697	18374	63035	14.2
	16 - 30%	C	0	0	0	35	21551	49499	25418	96503	21.7
	> 30%	CC	0	0	0	218	20792	57311	18167	96488	21.7
Soil depth	Deep		0	0	0	83	84474	159400	98559	342516	77.1
	Medium	C	0	0	0	0	0	2903	3572	6475	1.5
	Shallow	CC	0	0	0	181	29999	54509	9776	94465	21.3
Soil fertility	High		0	0	0	0	15922	24545	7033	47500	10.7
	Medium	C	0	0	0	83	67282	124128	68648	260141	58.5
	Low	CC	0	0	0	181	31269	68139	36226	135815	30.6
Soil drainage	Good		0	0	0	264	88671	196279	101250	386464	86.9
	Poor	CC	0	0	0	0	25802	20533	10657	56992	12.8
Soil texture	Medium/fine		0	0	0	170	103410	193878	101694	399152	89.8
	Sandy/stony	CC	0	0	0	0	4319	7649	3121	15089	3.4
	Cracking clay	C	0	0	0	94	6744	15286	7092	29216	6.6
Soil chemical constraints	None		0	0	0	264	112144	214012	110131	436551	98.2
	S/S/G*	CC	0	0	0	0	2329	2801	1776	6906	1.6
Miscellaneous land units		CC	0	0	0	0	374	559	94	1027	0.2
Total <i>without</i> constraints			0	0	0	0	2444	7403	0	9847	2.2
Total with <i>moderate</i> constraints		C	0	0	0	66	33934	72171	56655	162826	36.6
Total with <i>severe</i> constraints		CC	0	0	0	198	78469	137798	55346	271811	61.2
Total	(1000 ha)		0	0	0	264	114847	217371	112001	444483	100.0
	(%)		0.0	0.0	0.0	0.1	25.8	48.9	25.2	100.0	

* Salinity/Sodicity/Gypsum

C: Moderate or slight constraint

CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A19 Climate, soil and terrain constraints to rain-fed crop production - South Asia

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		115023	95162	135094	153894	93026	47034	0	639233	95.1
	LGP _{t=5} < 180	C	0	6927	5421	3528	0	0	0	15876	2.4
	LGP _{t=5} < 120	CC	868	10254	5610	0	0	0	0	16732	2.5
Terrain slopes	0 - 8%		55915	32426	50584	94672	49633	15808	0	299038	44.5
	8 - 16%	C	22849	20253	16106	30902	12420	4538	0	107068	15.9
	16 - 30%	C	22678	24631	27699	18921	11278	7346	0	112553	16.8
	> 30%	CC	14449	35032	51735	12928	19696	19341	0	153181	22.8
Soil depth	Deep		81665	74269	102402	137213	76177	35395	0	507121	75.5
	Medium	C	0	0	24	779	1983	275	0	3061	0.5
	Shallow	CC	10105	21022	29396	17232	12989	10933	0	101677	15.1
Soil fertility	High		57014	55651	87495	86163	36393	9264	0	331980	49.4
	Medium	C	6758	4280	7860	49815	38520	27506	0	134739	20.1
	Low	CC	27998	35361	36467	19246	16236	9833	0	145141	21.6
Soil drainage	Good		90600	93078	130254	150130	80646	40498	0	585206	87.1
	Poor	CC	1170	2213	1568	5094	10502	6105	0	26652	4.0
Soil texture	Medium/fine		57319	65512	93081	82938	73696	43708	0	416254	62.0
	Sandy/stony	CC	19968	18082	25531	55008	5716	597	0	124902	18.6
	Cracking clay	C	14483	11697	13211	17277	11736	2299	0	70703	10.5
Soil chemical constraints	None		67697	76686	113704	148517	87760	46115	0	540479	80.4
	S/S/G*	CC	24073	18606	18118	6706	3388	488	0	71379	10.6
Miscellaneous land units		CC	24121	17052	14302	2199	1878	430	0	59982	8.9
Total <i>without</i> constraints			0	0	0	20290	15396	2753	0	38439	5.7
Total with <i>moderate</i> constraints		C	0	0	52445	49543	36929	19063	0	157980	23.5
Total with <i>severe</i> constraints		CC	115891	112343	93679	87589	40702	25217	0	475421	70.8
Total	(1000 ha)		115891	112343	146124	157422	93026	47034	0	671840	100.0
	(%)		17.2	16.7	21.7	23.4	13.8	7.0	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A20 Climate, soil and terrain constraints to rain-fed crop production - East Asia

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		184969	35651	67521	53144	108982	220562	1671	672500	60.5
	LGP _{t=5} < 180	C	60011	43842	66075	85051	0	0	0	254979	22.9
	LGP _{t=5} < 120	CC	40663	58645	85507	0	0	0	0	184815	16.6
Terrain slopes	0 - 8%		118802	35149	53389	32124	19704	52261	153	311582	28.0
	8 - 16%	C	81561	30152	38819	20702	11411	31539	111	214295	19.3
	16 - 30%	C	53125	33589	71173	44210	28559	61155	277	292088	26.3
	> 30%	CC	32154	39249	55723	41159	49308	75607	1130	294330	26.5
Soil depth	Deep		176943	70622	115110	69342	54973	161081	581	648652	58.3
	Medium	C	11539	191	0	0	0	0	0	11730	1.1
	Shallow	CC	29391	30547	63752	56661	46073	52190	1090	279704	25.1
Soil fertility	High		120959	57555	97600	56113	42277	45422	202	420128	37.8
	Medium	C	1460	3948	12495	23121	21522	86552	106	149204	13.4
	Low	CC	95454	39857	68767	46769	37247	81297	1363	370754	33.3
Soil drainage	Good		208523	98074	159259	101117	86357	173229	1557	828116	74.5
	Poor	CC	9350	3286	19603	24885	14689	40041	114	111968	10.1
Soil texture	Medium/fine		203124	99363	174046	124300	98029	200577	1671	901110	81.0
	Sandy/stony	CC	0	19	1223	1055	1045	8622	0	11964	1.1
	Cracking clay	C	14750	1978	3593	648	1971	4071	0	27011	2.4
Soil chemical constraints	None		163182	89222	160783	115865	99084	211660	1671	841467	75.7
	S/S/G*	CC	54692	12138	18079	10138	1962	1610	0	98619	8.9
Miscellaneous land units		CC	67769	36779	40242	12192	7936	7292	0	172210	15.5
Total <i>without</i> constraints			0	0	0	11145	11477	5391	0	28013	2.5
Total with <i>moderate</i> constraints		C	0	0	64892	27204	18382	62268	152	172898	15.5
Total with <i>severe</i> constraints		CC	285642	138139	154212	99845	79123	152904	1519	911384	81.9
Total	(1000 ha)		285642	138139	219104	138195	108982	220562	1671	1112295	100.0
	(%)		25.7	12.4	19.7	12.4	9.8	19.8	0.2	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A21 Climate, soil and terrain constraints to rain-fed crop production - Central Asia

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		0	278918	54054	7540	3836	986	0	345334	83.3
	LGP _{t=5} < 180	C	0	37112	17420	4098	0	0	0	58630	14.1
	LGP _{t=5} < 120	CC	211	9395	793	0	0	0	0	10399	2.5
Terrain slopes	0 - 8%		0	251666	25385	2342	328	357	0	280078	67.6
	8 - 16%	C	3	46825	12545	1208	369	124	0	61074	14.7
	16 - 30%	C	16	12907	14911	2729	942	206	0	31711	7.7
	> 30%	CC	191	14028	19426	5359	2196	300	0	41500	10.0
Soil depth	Deep		19	203783	42090	6088	1865	757	0	254602	61.4
	Medium	C	0	0	0	0	0	0	0	0	0.0
	Shallow	CC	91	38784	18462	4834	1959	230	0	64360	15.5
Soil fertility	High		2	146039	36347	4402	933	173	0	187896	45.3
	Medium	C	20	11754	7474	2107	1028	577	0	22960	5.5
	Low	CC	89	84774	16732	4413	1863	236	0	108107	26.1
Soil drainage	Good		111	220371	54802	10111	3489	938	0	289822	69.9
	Poor	CC	0	22197	5751	811	335	48	0	29142	7.0
Soil texture	Medium/fine		111	206502	55954	9729	3697	944	0	276937	66.8
	Sandy/stony	CC	0	192	171	225	82	31	0	701	0.2
	Cracking clay	C	0	35874	4429	968	45	11	0	41327	10.0
Soil chemical constraints	None		111	97583	49329	10507	3824	986	0	162340	39.2
	S/S/G*	CC	0	144985	11223	415	0	0	0	156623	37.8
Miscellaneous land units		CC	100	82858	11714	716	12	0	0	95400	23.0
Total <i>without</i> constraints			0	0	0	1418	243	34	0	1695	0.4
Total with <i>moderate</i> constraints		C	0	0	26225	2846	1059	542	0	30672	7.4
Total with <i>severe</i> constraints		CC	211	325426	46041	7375	2534	410	0	381997	92.2
Total	(1000 ha)		211	325426	72267	11639	3836	986	0	414365	100.0
	(%)		0.1	78.5	17.4	2.8	0.9	0.2	0.0	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A22 Climate, soil and terrain constraints to rain-fed crop production - Japan

Constraints			0 days CC	1-60 days CC	60-119 days C	120-179 days	180-269 days	270-365 days	365+ days C	Totals	
										(1000 ha)	(%)
Temperature	LGP _{t=5} > 180		0	0	0	0	23002	12356	652	36010	96.9
	LGP _{t=5} < 180	C	0	0	0	1168	0	0	0	1168	3.1
	LGP _{t=5} < 120	CC	0	0	0	0	0	0	0	0	0.0
Terrain slopes	0 - 8%		0	0	0	115	3338	2977	124	6554	17.6
	8 - 16%	C	0	0	0	125	2920	1695	116	4856	13.1
	16 - 30%	C	0	0	0	383	7867	3909	250	12409	33.4
	> 30%	CC	0	0	0	545	8877	3775	161	13358	35.9
Soil depth	Deep		0	0	0	358	10638	10282	477	21755	58.5
	Medium	C	0	0	0	0	0	0	0	0	0.0
	Shallow	CC	0	0	0	810	12364	2004	174	15352	41.3
Soil fertility	High		0	0	0	174	5729	3563	100	9566	25.7
	Medium	C	0	0	0	528	11654	6443	378	19003	51.1
	Low	CC	0	0	0	467	5619	2281	174	8541	23.0
Soil drainage	Good		0	0	0	1165	22324	11664	652	35805	96.3
	Poor	CC	0	0	0	2	677	623	0	1302	3.5
Soil texture	Medium/fine		0	0	0	1106	21878	12090	643	35717	96.1
	Sandy/stony	CC	0	0	0	62	1124	196	9	1391	3.7
	Cracking clay	C	0	0	0	0	0	0	0	0	0.0
Soil chemical constraints	None		0	0	0	1168	23002	12287	652	37109	99.8
	S/S/G*	CC	0	0	0	0	0	0	0	0	0.0
Miscellaneous land units		CC	0	0	0	0	0	70	0	70	0.2
Total <i>without</i> constraints			0	0	0	0	1742	1834	0	3576	9.6
Total with <i>moderate</i> constraints		C	0	0	0	242	5790	5367	351	11750	31.6
Total with <i>severe</i> constraints		CC	0	0	0	926	15470	5156	301	21853	58.8
Total	(1000 ha)		0	0	0	1168	23002	12356	652	37178	100.0
	(%)		0.0	0.0	0.0	3.1	61.9	33.2	1.8	100.0	

* Salinity/Sodicity/Gypsum
C: Moderate or slight constraint
CC: Severe constraint

Notes Individual constraints are non-additive, i.e., they may overlap.

In areas with 365 days temperature growing periods, LGP 0 days is referred to as Hyper-arid moisture regime, LGP 1-60 days as Arid, LGP 60-119 days as Dry Semi-arid LGP 120-179 days as Moist Semi-arid, LGP 180-269 as Sub-humid, LGP 270-365 days as Humid, and LGP 365+ as Per-humid regime.

Table A23 Gross extents with cultivation potential for rain-fed cereals (1000 ha) - intermediate input level

REGION	NAME	TOTAL ³⁷	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	58101	138333	102550	14.0	87590	18.1	1751924	81.9
21	Eastern Europe	170952	23125	40632	39337	60.3	23604	74.1	44254	25.9
22	Northern Europe	172524	7905	16118	14005	22.0	9817	27.7	124679	72.3
23	Southern Europe	131643	7297	13512	16069	28.0	13540	38.3	81225	61.7
24	Western Europe	109547	20214	22311	15493	53.0	9230	61.4	42299	38.6
25	Russian Fed.	1674146	29461	79188	73301	10.9	80533	15.7	1411663	84.3
		2258812	88002	171761	158205	18.5	136724	24.6	1704120	75.4
31	Caribbean	23397	2888	3168	2652	37.2	1376	43.1	13313	56.9
32	Central America	248353	10061	15218	14526	16.0	12056	20.9	196492	79.1
		271750	12949	18386	17178	17.9	13432	22.8	209805	77.2
41	South America	1777573	129633	267930	178526	32.4	178166	42.4	1023318	57.6
51	Oceania	793540	20903	29102	37384	11.0	28892	14.7	677259	85.3
52	Polynesia	56118	215	1353	1138	4.8	4352	12.6	49060	87.4
		849658	21118	30455	38522	10.6	33244	14.5	726319	85.5
61	Eastern Africa	639474	39774	81932	93996	33.7	57394	42.7	366378	57.3
62	Middle Africa	657061	49793	84460	82549	33.0	58757	41.9	381502	58.1
63	Northern Africa	794112	19415	25473	24948	8.8	19282	11.2	704994	88.8
64	Southern Africa	266428	2367	7600	14446	9.2	13306	14.2	228709	85.8
65	Western Africa	632996	21984	83933	58792	26.0	29351	30.7	438936	69.3
		2990071	133333	283398	274731	23.1	178090	29.1	2120519	70.9
71	Western Asia	432992	1105	6246	15445	5.3	14979	8.7	395217	91.3
81	Southeast. Asia	444483	13273	31033	30337	16.8	33157	24.3	336683	75.7
82	South Asia	671842	60342	62476	36319	23.7	26013	27.6	486692	72.4
84	East Asia	1112296	13682	40605	46031	9.0	43633	12.9	968345	87.1
85	Central Asia	414363	815	1798	7956	2.6	13942	5.9	389852	94.1
86	Japan	37178	1588	3780	3413	23.6	2741	31.0	25656	69.0
		2680162	89700	139692	124056	13.2	119486	17.6	2207228	82.4
	DEVELOPING	8171488	365347	713225	607661	20.6	505764	26.8	5979491	73.2
	DEVELOPED	5228028	168594	342976	301552	15.6	255947	20.4	4158959	79.6
	WORLD TOTAL	13399516	533941	1056201	909213	18.7	761711	24.3	10138450	75.7

³⁷ Total extent derived from digital version of the Soil Map of the World (FAO, 1995c).

Table A24 Gross extents with cultivation potential for rain-fed root and tuber crops (1000 ha) - intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	7697	50970	109676	7.9	133873	14.1	1836282	85.9
21	Eastern Europe	170952	12759	20906	32195	38.5	27226	54.5	77866	45.5
22	Northern Europe	172524	4957	7027	8300	11.8	16304	21.2	135936	78.8
23	Southern Europe	131643	649	4791	9837	11.6	10438	19.5	105928	80.5
24	Western Europe	109547	2022	10667	20275	30.1	13836	42.7	62747	57.3
25	Russian Fed.	1674146	17376	66487	61981	8.7	60911	12.3	1467391	87.7
		2258812	37763	109878	132588	12.4	128715	18.1	1849868	81.9
31	Caribbean	23397	2165	3356	1757	31.1	1190	36.2	14929	63.8
32	Central America	248353	4744	11180	9836	10.4	9009	14.0	213584	86.0
		271750	6909	14536	11593	12.2	10199	15.9	228513	84.1
41	South America	1777573	56759	202812	162248	23.7	156478	32.5	1199276	67.5
51	Oceania	793540	3385	10310	19807	4.2	23732	7.2	736306	92.8
52	Polynesia	56118	111	683	666	2.6	3197	8.3	51461	91.7
		849658	3496	10993	20473	4.1	26929	7.3	787767	92.7
61	Eastern Africa	639474	11657	37990	54252	16.2	52742	24.5	482833	75.5
62	Middle Africa	657061	14536	69582	78614	24.8	80174	37.0	414155	63.0
63	Northern Africa	794112	1441	12409	16981	3.9	13002	5.5	750279	94.5
64	Southern Africa	266428	251	1848	3580	2.1	5941	4.4	254808	95.6
65	Western Africa	632996	10046	40890	35243	13.6	20861	16.9	525956	83.1
		2990071	37931	162719	188670	13.0	172720	18.8	2428031	81.2
71	Western Asia	432992	52	262	1794	0.5	3962	1.4	426922	98.6
81	Southeast. Asia	444483	8231	22508	23246	12.1	26134	18.0	364364	82.0
82	South Asia	671842	9722	27730	30622	10.1	37031	15.6	566737	84.4
84	East Asia	1112296	4197	18379	36091	5.3	43595	9.2	1010034	90.8
85	Central Asia	414363	178	703	853	0.4	2249	1.0	410380	99.0
86	Japan	37178	445	1834	2532	12.9	3235	21.6	29132	78.4
		2680162	22773	71154	93344	7.0	112244	11.2	2380647	88.8
	DEVELOPING	8171488	124090	450332	455783	12.6	455565	18.2	6685718	81.8
	DEVELOPED	5228028	49290	172992	264603	9.3	289555	14.9	4451588	85.1
	WORLD TOTAL	13399516	173380	623324	720386	11.3	745120	16.9	11137306	83.1

Table A25 Gross extents with cultivation potential for rain-fed pulses (1000 ha) - intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	17657	67530	104363	8.9	69668	12.1	1879280	87.9
21	Eastern Europe	170952	14853	27577	26868	40.5	16957	50.5	84697	49.5
22	Northern Europe	172524	2947	9368	7321	11.4	4399	13.9	148489	86.1
23	Southern Europe	131643	2212	5129	6312	10.4	3448	13.0	114542	87.0
24	Western Europe	109547	6899	13879	12851	30.7	10099	39.9	65819	60.1
25	Russian Fed.	1674146	6744	50493	62468	7.2	40286	9.6	1514155	90.4
		2258812	33655	106446	115820	11.3	75189	14.7	1927702	85.3
31	Caribbean	23397	929	2625	2848	27.4	1847	35.3	15148	64.7
32	Central America	248353	4393	8994	11269	9.9	9212	13.6	214485	86.4
		271750	5322	11619	14117	11.4	11059	15.5	229633	84.5
41	South America	1777573	26146	89094	193639	17.4	174984	27.2	1293710	72.8
51	Oceania	793540	5120	14108	19907	4.9	19582	7.4	734823	92.6
52	Polynesia	56118	48	287	666	1.8	641	2.9	54476	97.1
		849658	5168	14395	20573	4.7	20223	7.1	789299	92.9
61	Eastern Africa	639474	26782	64323	75793	26.1	55797	34.8	416779	65.2
62	Middle Africa	657061	12980	40936	80554	20.5	76350	32.1	446241	67.9
63	Northern Africa	794112	12048	19358	14663	5.8	15093	7.7	732950	92.3
64	Southern Africa	266428	1338	4425	7287	4.9	10043	8.7	243335	91.3
65	Western Africa	632996	6811	44096	50180	16.0	45820	23.2	486089	76.8
		2990071	59959	173138	228477	15.4	203103	22.2	2325394	77.8
71	Western Asia	432992	417	367	777	0.4	651	0.5	430780	99.5
81	Southeast. Asia	444483	1499	15833	21602	8.8	20573	13.4	384976	86.6
82	South Asia	671842	13307	52587	36376	15.2	27395	19.3	542177	80.7
84	East Asia	1112296	4336	21441	32562	5.2	36327	8.5	1017630	91.5
85	Central Asia	414363	40	606	1602	0.5	3192	1.3	408923	98.7
86	Japan	37178	496	2227	3079	15.6	2993	23.7	28383	76.3
		2680162	19678	92694	95221	7.7	90480	11.1	2382089	88.9
	DEVELOPING	8171488	111074	364972	529818	12.3	477925	18.2	6687699	81.8
	DEVELOPED	5228028	56928	190311	243169	9.4	167432	12.6	4570188	87.4
	WORLD TOTAL	13399516	168002	555283	772987	11.2	645357	16.0	11257887	84.0

Table A26 Gross extents with cultivation potential for rain-fed oil crops (1000 ha) - intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	16288	96819	142621	12.0	81023	15.7	1801747	84.3
21	Eastern Europe	170952	19180	29927	31713	47.3	28942	64.2	61190	35.8
22	Northern Europe	172524	6085	9150	11535	15.5	9453	21.0	136301	79.0
23	Southern Europe	131643	4840	14161	16361	26.9	15090	38.3	81191	61.7
24	Western Europe	109547	7504	15974	19366	39.1	15212	53.0	51491	47.0
25	Russian Fed.	1674146	24302	46492	46857	7.0	69057	11.2	1487438	88.8
		2258812	61911	115704	125832	13.4	137754	19.5	1817611	80.5
31	Caribbean	23397	1156	3052	2562	28.9	2026	37.6	14601	62.4
32	Central America	248353	6806	11379	12779	12.5	10934	16.9	206455	83.1
		271750	7962	14431	15341	13.9	12960	18.7	221056	81.3
41	South America	1777573	49020	191935	229954	26.5	201070	37.8	1105594	62.2
51	Oceania	793540	9320	25658	32820	8.5	42008	13.8	683734	86.2
52	Polynesia	56118	465	2617	5196	14.8	2456	19.1	45384	80.9
		849658	9785	28275	38016	9.0	44464	14.2	729118	85.8
61	Eastern Africa	639474	31738	90285	72356	30.4	50226	38.3	394869	61.7
62	Middle Africa	657061	20317	92552	84282	30.0	83405	42.7	376505	57.3
63	Northern Africa	794112	13879	28952	23144	8.3	21393	11.0	706744	89.0
64	Southern Africa	266428	1041	6693	12415	7.6	15629	13.4	230650	86.6
65	Western Africa	632996	8324	61972	56066	20.0	53855	28.5	452779	71.5
		2990071	75299	280454	248263	20.2	224508	27.7	2161547	72.3
71	Western Asia	432992	2094	5048	7184	3.3	7835	5.1	410831	94.9
81	Southeast. Asia	444483	7869	29161	39587	17.2	28363	23.6	339503	76.4
82	South Asia	671842	21908	61224	50884	19.9	30893	24.5	506933	75.5
84	East Asia	1112296	5347	17311	29416	4.7	38394	8.1	1021828	91.9
85	Central Asia	414363	502	1129	1688	0.8	5829	2.2	405215	97.8
86	Japan	37178	872	2939	3217	18.9	3236	27.6	26914	72.4
		2680162	36498	111764	124792	10.2	106715	14.2	2300393	85.8
	DEVELOPING	8171488	170466	603310	627513	17.1	552308	23.9	6217891	76.1
	DEVELOPED	5228028	88391	241120	304490	12.1	264021	17.2	4330006	82.8
	WORLD TOTAL	13399516	258857	844430	932003	15.2	816329	21.3	10547897	78.7

Table A27 Gross extents with cultivation potential for rain-fed sugar crops (1000 ha) - intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	14042	73899	77636	7.7	50780	10.1	1922141	89.9
21	Eastern Europe	170952	5844	21346	18829	26.9	12138	34.0	112795	66.0
22	Northern Europe	172524	138	5754	9395	8.9	9641	14.4	147596	85.6
23	Southern Europe	131643	1770	6758	6809	11.7	4591	15.1	111715	84.9
24	Western Europe	109547	7275	13569	9611	27.8	6088	33.4	73004	66.6
25	Russian Fed.	1674146	47	3131	32729	2.1	62155	5.9	1576084	94.1
		2258812	15074	50558	77373	6.3	94613	10.5	2021194	89.5
31	Caribbean	23397	1331	2420	2360	26.1	1652	33.2	15634	66.8
32	Central America	248353	1676	6313	8227	6.5	6887	9.3	225250	90.7
		271750	3007	8733	10587	8.2	8539	11.4	240884	88.6
41	South America	1777573	33906	81767	187859	17.1	174208	26.9	1299833	73.1
51	Oceania	793540	2770	6439	10136	2.4	14272	4.2	759923	95.8
52	Polynesia	56118	111	784	2639	6.3	4837	14.9	47747	85.1
		849658	2881	7223	12775	2.7	19109	4.9	807670	95.1
61	Eastern Africa	639474	750	6969	13771	3.4	28051	7.7	589933	92.3
62	Middle Africa	657061	4327	45002	52556	15.5	46890	22.6	508286	77.4
63	Northern Africa	794112	0	536	4449	0.6	11348	2.1	777779	97.9
64	Southern Africa	266428	44	288	966	0.5	1840	1.2	263290	98.8
65	Western Africa	632996	123	2347	11429	2.2	24481	6.1	594616	93.9
		2990071	5244	55142	83171	4.8	112610	8.6	2733904	91.4
71	Western Asia	432992	77	372	1027	0.3	1392	0.7	430124	99.3
81	Southeast. Asia	444483	1471	8199	29177	8.7	41347	18.0	364289	82.0
82	South Asia	671842	409	3575	11075	2.2	22802	5.6	633981	94.4
84	East Asia	1112296	2775	11514	21840	3.2	27073	5.7	1049094	94.3
85	Central Asia	414363	44	240	446	0.2	746	0.4	412887	99.6
86	Japan	37178	854	2276	2693	15.7	2832	23.3	28523	76.7
		2680162	5553	25804	65231	3.6	94800	7.1	2488774	92.9
	DEVELOPING	8171488	47044	170326	347821	6.9	393554	11.7	7212743	88.3
	DEVELOPED	5228028	32740	133172	167838	6.4	162497	9.5	4731781	90.5
	WORLD TOTAL	13399516	79784	303498	515659	6.7	556051	10.9	11944524	89.1

Table A28 Gross extents with cultivation potential for rain-fed cotton (1000 ha) - intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	554	2087	7229	0.5	21576	1.5	2107052	98.5
21	Eastern Europe	170952	0	0	0	0.0	23	0.0	170929	100.0
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	0	0	135	0.1	362	0.4	131146	99.6
24	Western Europe	109547	0	0	0	0.0	0	0.0	109547	100.0
25	Russian Fed.	1674146	0	0	0	0.0	133	0.0	1674013	100.0
		2258812	0	0	135	0.0	518	0.0	2258159	100.0
31	Caribbean	23397	0	394	1730	9.1	2837	21.2	18436	78.8
32	Central America	248353	1898	3618	5896	4.6	7462	7.6	229479	92.4
		271750	1898	4012	7626	5.0	10299	8.8	247915	91.2
41	South America	1777573	3680	29778	63845	5.5	114413	11.9	1565857	88.1
51	Oceania	793540	4046	12895	16324	4.2	13271	5.9	747004	94.1
52	Polynesia	56118	62	77	210	0.6	303	1.2	55466	98.8
		849658	4108	12972	16534	4.0	13574	5.6	802470	94.4
61	Eastern Africa	639474	13991	42766	56381	17.7	54111	26.2	472225	73.8
62	Middle Africa	657061	6403	15618	28907	7.8	46369	14.8	559764	85.2
63	Northern Africa	794112	9035	17572	15983	5.4	17258	7.5	734264	92.5
64	Southern Africa	266428	19	388	2447	1.1	6297	3.4	257277	96.6
65	Western Africa	632996	5920	28241	35123	10.9	33494	16.2	530218	83.8
		2990071	35368	104585	138841	9.3	157529	14.6	2553748	85.4
71	Western Asia	432992	0	0	243	0.1	473	0.2	432276	99.8
81	Southeast. Asia	444483	300	1063	7937	2.1	14851	5.4	420332	94.6
82	South Asia	671842	22627	57464	53941	19.9	28817	24.2	508993	75.8
84	East Asia	1112296	0	386	2378	0.2	7731	0.9	1101801	99.1
85	Central Asia	414363	0	0	155	0.0	390	0.1	413818	99.9
86	Japan	37178	0	0	0	0.0	278	0.7	36900	99.3
		2680162	22927	58913	64411	5.5	52067	7.4	2481844	92.6
	DEVELOPING	8171488	63935	197365	275176	6.6	334806	10.7	7300206	89.3
	DEVELOPED	5228028	4600	14982	23688	0.8	35643	1.5	5149115	98.5
	WORLD TOTAL	13399516	68535	212347	298864	4.3	370449	7.1	12449321	92.9

Table A29 Gross extents with cultivation potential for rain-fed cereals (1000ha) - high input level

REGION	NAME	TOTAL ³⁸	VS	S	MS	% VS+S MS	mS	% VS+S+MS+mS	NS	%NS
11	North America	2138498	88731	130385	69697	13.5	38335	15.3	1811350	84.7
21	Eastern Europe	170952	21874	41697	32047	55.9	17711	66.3	57623	33.7
22	Northern Europe	172524	6635	21242	13057	23.7	9058	29.0	122532	71.0
23	Southern Europe	131643	6508	8767	6052	16.2	2666	18.2	107650	81.8
24	Western Europe	109547	17673	20276	11796	45.4	5644	50.6	54158	49.4
25	Russian Fed.	1674146	26789	62807	87762	10.6	45487	13.3	1451301	86.7
		2258812	79479	154789	150714	17.0	80566	20.6	1793264	79.4
31	Caribbean	23397	4055	3445	1583	38.8	611	41.4	13703	58.6
32	Central America	248353	13402	16304	9155	15.6	3201	16.9	206291	83.1
		271750	17457	19749	10738	17.6	3812	19.0	219994	81.0
41	South America	1777573	220063	297140	180779	39.3	125759	46.3	953832	53.7
51	Oceania	793540	27017	26508	20340	9.3	11178	10.7	708497	89.3
52	Polynesia	56118	1088	2304	4242	13.6	7481	26.9	41003	73.1
		849658	28105	28812	24582	9.6	18659	11.8	749500	88.2
61	Eastern Africa	639474	73794	80540	57164	33.1	21100	36.4	406876	63.6
62	Middle Africa	657061	103090	117349	70201	44.2	22947	47.7	343474	52.3
63	Northern Africa	794112	45471	25425	12303	10.5	6139	11.3	704774	88.7
64	Southern Africa	266428	2196	4067	4088	3.9	1990	4.6	254087	95.4
65	Western Africa	632996	60173	76166	44164	28.5	19070	31.5	433423	68.5
		2990071	284724	303547	187920	26.0	71246	28.3	2142634	71.7
71	Western Asia	432992	824	4189	6055	2.6	2967	3.2	418957	96.8
81	Southeast. Asia	444483	37632	50917	28857	26.4	32480	33.7	294597	66.3
82	South Asia	671842	94278	71252	26814	28.6	7845	29.8	471653	70.2
84	East Asia	1112296	40318	43563	31889	10.4	13814	11.7	982712	88.3
85	Central Asia	414363	519	759	4919	1.5	2809	2.2	405357	97.8
86	Japan	37178	2871	2415	1349	17.8	744	19.8	29799	80.2
		2680162	175618	168906	93828	16.4	57692	18.5	2184118	81.5
	DEVELOPING	8171488	696903	793420	482213	24.1	268213	27.4	5930739	72.6
	DEVELOPED	5228028	198098	314097	242100	14.4	130823	16.9	4342910	83.1
	WORLD TOTAL	13399516	895001	1107517	724313	20.4	399036	23.3	10273649	76.7

³⁸ Total extent derived from digital version of the Soil Map of the World (FAO, 1995c).

Table A30 Gross extents with cultivation potential for rain-fed roots and tuber crops (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S MS	mS	% VS+S+MS+mS	NS	%NS
11	North America	2138498	7148	47805	116431	8.0	100740	12.7	1866374	87.3
21	Eastern Europe	170952	7633	26714	32085	38.9	14541	47.4	89979	52.6
22	Northern Europe	172524	2437	6796	9930	11.1	9201	16.4	144160	83.6
23	Southern Europe	131643	825	2976	6297	7.7	4734	11.3	116811	88.7
24	Western Europe	109547	2079	6231	12996	19.4	11513	30.0	76728	70.0
25	Russian Fed.	1674146	7653	63661	59876	7.8	39167	10.2	1503789	89.8
		2258812	20627	106378	121184	11.0	79156	14.5	1931467	85.5
31	Caribbean	23397	4136	3320	1300	37.4	638	40.2	14003	59.8
32	Central America	248353	10920	14592	8633	13.7	5922	16.1	208286	83.9
		271750	15056	17912	9933	15.8	6560	18.2	222289	81.8
41	South America	1777573	166031	210351	156556	30.0	166572	39.4	1078063	60.6
51	Oceania	793540	4451	12174	16212	4.1	16037	6.2	744666	93.8
52	Polynesia	56118	948	550	1470	5.3	9377	22.0	43773	78.0
		849658	5399	12724	17682	4.2	25414	7.2	788439	92.8
61	Eastern Africa	639474	26652	56116	53339	21.3	38174	27.3	465193	72.7
62	Middle Africa	657061	60524	89335	92882	36.9	84938	49.9	329382	50.1
63	Northern Africa	794112	10564	22508	19941	6.7	11204	8.1	729895	91.9
64	Southern Africa	266428	255	498	866	0.6	1612	1.2	263197	98.8
65	Western Africa	632996	34118	48395	32711	18.2	17433	21.0	500339	79.0
		2990071	132113	216852	199739	18.4	153361	23.5	2288006	76.5
71	Western Asia	432992	56	318	669	0.2	439	0.3	431510	99.7
81	Southeast. Asia	444483	46364	32513	26495	23.7	41743	33.1	297368	66.9
82	South Asia	671842	27442	43596	38843	16.4	38738	22.1	523223	77.9
84	East Asia	1112296	7178	23632	34162	5.8	30580	8.6	1016744	91.4
85	Central Asia	414363	212	415	264	0.2	232	0.3	413240	99.7
86	Japan	37178	981	1643	1406	10.8	2235	16.9	30913	83.1
		2680162	82177	101799	101170	10.6	113528	14.9	2281488	85.1
	DEVELOPING	8171488	395400	546139	468131	17.3	447602	22.7	6314216	77.3
	DEVELOPED	5228028	33207	168000	255233	8.7	198168	12.5	4573420	87.5
	WORLD TOTAL	13399516	428607	714139	723364	13.9	645770	18.7	10887636	81.3

Table A31 Gross extents with cultivation potential for rain-fed pulses (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S MS	mS	% VS+S+MS+mS	NS	%NS
11	North America	2138498	21146	80537	65618	7.8	22586	8.9	1948611	91.1
21	Eastern Europe	170952	9526	20078	9507	22.9	825	23.4	131016	76.6
22	Northern Europe	172524	1179	2516	1683	3.1	1149	3.8	165997	96.2
23	Southern Europe	131643	2041	5716	1711	7.2	574	7.6	121601	92.4
24	Western Europe	109547	6263	4921	2635	12.6	616	13.2	95112	86.8
25	Russian Fed.	1674146	5892	47326	19620	4.4	3263	4.5	1598045	95.5
		2258812	24901	80557	35156	6.2	6427	6.5	2111771	93.5
31	Caribbean	23397	1402	3326	2536	31.0	1634	38.0	14499	62.0
32	Central America	248353	7308	11509	10108	11.6	8023	14.9	211405	85.1
		271750	8710	14835	12644	13.3	9657	16.9	225904	83.1
41	South America	1777573	36104	164193	223175	23.8	176612	33.8	1177489	66.2
51	Oceania	793540	7523	15789	18695	5.3	11261	6.7	740272	93.3
52	Polynesia	56118	117	693	645	2.6	3353	8.6	51310	91.4
		849658	7640	16482	19340	5.1	14614	6.8	791582	93.2
61	Eastern Africa	639474	62917	71327	53970	29.4	34706	34.9	416554	65.1
62	Middle Africa	657061	41226	76303	83719	30.6	91616	44.6	364197	55.4
63	Northern Africa	794112	26802	26391	13087	8.3	9414	9.5	718418	90.5
64	Southern Africa	266428	350	1329	3334	1.9	4838	3.7	256577	96.3
65	Western Africa	632996	33240	56496	48373	21.8	35946	27.5	458941	72.5
		2990071	164535	231846	202483	20.0	176520	25.9	2214687	74.1
71	Western Asia	432992	0	159	32	0.0	75	0.1	432726	99.9
81	Southeast. Asia	444483	16986	37704	24423	17.8	30635	24.7	334735	75.3
82	South Asia	671842	20299	71849	50872	21.3	16370	23.7	512452	76.3
84	East Asia	1112296	10160	36740	35885	7.4	25062	9.7	1004449	90.3
85	Central Asia	414363	162	193	160	0.1	244	0.2	413604	99.8
86	Japan	37178	1327	2853	1842	16.2	1008	18.9	30148	81.1
		2680162	48934	149339	113182	11.6	73319	14.4	2295388	85.6
	DEVELOPING	8171488	257073	558212	550319	16.7	438528	22.1	6367356	77.9
	DEVELOPED	5228028	54897	179736	121311	6.8	41282	7.6	4830802	92.4
	WORLD TOTAL	13399516	311970	737948	671630	12.8	479810	16.4	11198158	83.6

Table A32 Gross extents with cultivation potential for rain-fed oil crops (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S MS	mS	% VS+S+MS+mS	NS	%NS
11	North America	2138498	12456	76481	132788	10.4	74949	13.9	1841824	86.1
21	Eastern Europe	170952	12418	23605	35161	41.6	22106	54.6	77662	45.4
22	Northern Europe	172524	3571	9908	14273	16.1	9125	21.4	135647	78.6
23	Southern Europe	131643	2890	9709	7492	15.3	6020	19.8	105532	80.2
24	Western Europe	109547	6599	8415	19659	31.7	6834	37.9	68040	62.1
25	Russian Fed.	1674146	22219	37731	36467	5.8	69194	9.9	1508535	90.1
		2258812	47697	89368	113052	11.1	113279	16.1	1895416	83.9
31	Caribbean	23397	1090	2444	3915	31.8	1919	40.0	14029	60.0
32	Central America	248353	11108	10627	11654	13.4	8832	17.0	206132	83.0
		271750	12198	13071	15569	15.0	10751	19.0	220161	81.0
41	South America	1777573	146383	267376	237711	36.6	208420	48.4	917683	51.6
51	Oceania	793540	11500	25388	34357	9.0	23040	11.9	699255	88.1
52	Polynesia	56118	6887	3191	3119	23.5	3053	29.0	39868	71.0
		849658	18387	28579	37476	9.9	26093	13.0	739123	87.0
61	Eastern Africa	639474	74475	89478	46022	32.8	26204	36.9	403295	63.1
62	Middle Africa	657061	85490	113846	99814	45.5	78946	57.5	278965	42.5
63	Northern Africa	794112	27221	31674	17083	9.6	13275	11.2	704859	88.8
64	Southern Africa	266428	591	2307	6309	3.5	6089	5.7	251132	94.3
65	Western Africa	632996	52004	53432	55199	25.4	38857	31.5	433504	68.5
		2990071	239781	290737	224427	25.2	163371	30.7	2071755	69.3
71	Western Asia	432992	1161	2542	3621	1.7	3922	2.6	421746	97.4
81	Southeast. Asia	444483	47773	42381	47338	30.9	27168	37.0	279823	63.0
82	South Asia	671842	41771	79410	64404	27.6	20708	30.7	465549	69.3
84	East Asia	1112296	12944	22070	32674	6.1	26448	8.5	1018160	91.5
85	Central Asia	414363	343	352	395	0.3	2932	1.0	410341	99.0
86	Japan	37178	1842	2369	1685	15.9	1327	19.4	29955	80.6
		2680162	104673	146582	146496	14.8	78583	17.8	2203828	82.2
	DEVELOPING	8171488	509241	721130	629258	22.8	466773	28.5	5845086	71.5
	DEVELOPED	5228028	73495	193606	281882	10.5	212595	14.6	4466450	85.4
	WORLD TOTAL	13399516	582736	914736	911140	18.0	679368	23.0	10311536	77.0

Table A33 Gross extents with cultivation potential for rain-fed sugar crops (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S MS	mS	% VS+S+MS+mS	NS	%NS
11	North America	2138498	13916	42566	44034	4.7	28495	6.0	2009487	94.0
21	Eastern Europe	170952	4968	3608	1096	5.7	312	5.8	160968	94.2
22	Northern Europe	172524	27	1424	4718	3.6	4390	6.1	161965	93.9
23	Southern Europe	131643	1861	3519	2262	5.8	633	6.3	123368	93.7
24	Western Europe	109547	5613	4322	1376	10.3	261	10.6	97975	89.4
25	Russian Fed.	1674146	497	3951	12484	1.0	37229	3.2	1619985	96.8
		2258812	12966	16824	21936	2.3	42825	4.2	2164261	95.8
31	Caribbean	23397	1151	3658	3070	33.7	662	36.5	14856	63.5
32	Central America	248353	5616	9299	8346	9.4	5708	11.7	219384	88.3
		271750	6767	12957	11416	11.5	6370	13.8	234240	86.2
41	South America	1777573	49368	143689	278488	26.5	224469	39.2	1081559	60.8
51	Oceania	793540	2511	5099	6482	1.8	9866	3.0	769582	97.0
52	Polynesia	56118	514	4065	6738	20.2	4361	27.9	40440	72.1
		849658	3025	9164	13220	3.0	14227	4.7	810022	95.3
61	Eastern Africa	639474	3462	9128	21027	5.3	43155	12.0	562702	88.0
62	Middle Africa	657061	34571	85814	77516	30.1	68342	40.5	390818	59.5
63	Northern Africa	794112	0	1529	5144	0.8	22784	3.7	764655	96.3
64	Southern Africa	266428	45	119	289	0.2	199	0.2	265776	99.8
65	Western Africa	632996	940	7454	21565	4.7	37204	10.6	565833	89.4
		2990071	39018	104044	125541	9.0	171684	14.7	2549784	85.3
71	Western Asia	432992	414	309	415	0.3	244	0.3	431610	99.7
81	Southeast. Asia	444483	3741	31217	61903	21.8	44295	31.8	303327	68.2
82	South Asia	671842	1450	8546	19656	4.4	33119	9.3	609071	90.7
84	East Asia	1112296	6653	26241	32320	5.9	18797	7.6	1028285	92.4
85	Central Asia	414363	65	79	96	0.1	198	0.1	413925	99.9
86	Japan	37178	1404	2460	2154	16.2	1055	19.0	30105	81.0
		2680162	13313	68543	116129	7.4	97464	11.0	2384713	89.0
	DEVELOPING	8171488	107990	331147	536573	11.9	503537	18.1	6692241	81.9
	DEVELOPED	5228028	30797	66949	74606	3.3	82241	4.9	4973435	95.1
	WORLD TOTAL	13399516	138787	398096	611179	8.6	585778	12.9	11665676	87.1

Table A34 Gross extents with cultivation potential for rain-fed cotton (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S MS	mS	% VS+S+MS+mS	NS	%NS
11	North America	2138498	1054	2316	3559	0.3	6692	0.6	2124877	99.4
21	Eastern Europe	170952	0	0	0	0.0	0	0.0	170952	100.0
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	0	0	0	0.0	0	0.0	131643	100.0
24	Western Europe	109547	0	0	0	0.0	0	0.0	109547	100.0
25	Russian Fed.	1674146	0	0	0	0.0	0	0.0	1674146	100.0
		2258812	0	0	0	0.0	0	0.0	2258812	100.0
31	Caribbean	23397	0	292	2152	10.4	3554	25.6	17399	74.4
32	Central America	248353	3740	4184	4835	5.1	7116	8.0	228478	92.0
		271750	3740	4476	6987	5.6	10670	9.5	245877	90.5
41	South America	1777573	6576	33652	71551	6.3	137213	14.0	1528581	86.0
51	Oceania	793540	4612	15017	12182	4.0	5683	4.7	756046	95.3
52	Polynesia	56118	90	86	315	0.9	440	1.7	55187	98.3
		849658	4702	15103	12497	3.8	6123	4.5	811233	95.5
61	Eastern Africa	639474	32944	56024	53730	22.3	32226	27.4	464550	72.6
62	Middle Africa	657061	17568	26944	41924	13.2	52771	21.2	517854	78.8
63	Northern Africa	794112	21232	25279	13597	7.6	10404	8.9	723600	91.1
64	Southern Africa	266428	3	345	1351	0.6	1462	1.2	263267	98.8
65	Western Africa	632996	18862	42440	38322	15.7	35312	21.3	498060	78.7
		2990071	90609	151032	148924	13.1	132175	17.5	2467331	82.5
71	Western Asia	432992	0	0	0	0.0	0	0.0	432992	100.0
81	Southeast. Asia	444483	590	3508	22690	6.0	35996	14.1	381699	85.9
82	South Asia	671842	40589	83846	47429	25.6	16619	28.1	483359	71.9
84	East Asia	1112296	0	118	836	0.1	12833	1.2	1098509	98.8
85	Central Asia	414363	0	0	0	0.0	0	0.0	414363	100.0
86	Japan	37178	0	0	0	0.0	1152	3.1	36026	96.9
		2680162	41179	87472	70955	7.4	66600	9.9	2413956	90.1
	DEVELOPING	8171488	142194	276718	298732	8.8	345946	13.0	7107898	87.0
	DEVELOPED	5228028	5666	17333	15741	0.7	13527	1.0	5175761	99.0
	WORLD TOTAL	13399516	147860	294051	314473	5.6	359473	8.3	12283659	91.7

Table A35 Gross extents with cultivation potential for rain-fed plus irrigated cereals (1000 ha) - intermediate input level

REGION	NAME	TOTAL ³⁹	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	83358	137565	97233	14.9	76474	18.5	1743868	81.5
21	Eastern Europe	170952	26738	41297	37408	61.7	21797	74.4	43712	25.6
22	Northern Europe	172524	8584	15557	13899	22.0	9807	27.7	124677	72.3
23	Southern Europe	131643	9836	13105	15194	29.0	12844	38.7	80664	61.3
24	Western Europe	109547	21633	21839	14727	53.1	9131	61.5	42217	38.5
25	Russian Fed.	1674146	39671	89441	68471	11.8	66818	15.8	1409745	84.2
		2258812	106462	181239	149699	19.4	120397	24.7	1701015	75.3
31	Caribbean	23397	3142	3427	2348	38.1	1230	43.4	13250	56.6
32	Central America	248353	11325	16405	14595	17.0	10611	21.3	195417	78.7
		271750	14467	19832	16943	18.9	11841	23.2	208667	76.8
41	South America	1777573	146289	273503	177696	33.6	164869	42.9	1015216	57.1
51	Oceania	793540	42486	40236	29818	14.2	20244	16.7	660756	83.3
52	Polynesia	56118	215	1376	1189	5.0	4281	12.6	49057	87.4
		849658	42701	41612	31007	13.6	24525	16.5	709813	83.5
61	Eastern Africa	639474	46624	84995	91042	34.8	53918	43.3	362895	56.7
62	Middle Africa	657061	52200	89304	84580	34.4	52481	42.4	378496	57.6
63	Northern Africa	794112	28395	27817	26666	10.4	15669	12.4	695565	87.6
64	Southern Africa	266428	4375	8015	13801	9.8	12749	14.6	227488	85.4
65	Western Africa	632996	24451	86726	58976	26.9	27032	31.2	435811	68.8
		2990071	156045	296857	275065	24.3	161849	29.8	2100255	70.2
71	Western Asia	432992	5442	7633	14676	6.4	14228	9.7	391013	90.3
81	Southeast. Asia	444483	13329	31949	31036	17.2	31830	24.3	336339	75.7
82	South Asia	671842	69263	62729	37256	25.2	20735	28.3	481859	71.7
84	East Asia	1112296	21498	45098	43988	9.9	39738	13.5	961974	86.5
85	Central Asia	414363	4859	5204	7057	4.1	9616	6.5	387627	93.5
86	Japan	37178	1588	3864	3453	24.0	2659	31.1	25614	68.9
		2680162	110537	148844	122790	14.3	104578	18.2	2193413	81.8
	DEVELOPING	8171488	431407	744181	604906	21.8	458987	27.4	5932007	72.6
	DEVELOPED	5228028	233894	362904	280203	16.8	219774	21.0	4131253	79.0
	WORLD TOTAL	13399516	665301	1107085	885109	19.8	678761	24.9	10063260	75.1

³⁹ Total extent derived from digital version of the Soil Map of the World (FAO, 1995c).

Table A36 Gross extents with cultivation potential for rain-fed plus irrigated root and tubers (1000 ha) - Intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	21649	64026	99656	8.7	124601	14.5	1828566	85.5
21	Eastern Europe	170952	13498	23692	30649	39.7	25386	54.5	77727	45.5
22	Northern Europe	172524	4957	7532	7861	11.8	16238	21.2	135936	78.8
23	Southern Europe	131643	2324	5934	9227	13.3	9954	20.8	104204	79.2
24	Western Europe	109547	2965	11841	19238	31.1	13097	43.0	62406	57.0
25	Russian Fed.	1674146	20653	79373	61119	9.6	48652	12.5	1464349	87.5
		2258812	44397	128372	128094	13.3	113327	18.3	1844622	81.7
31	Caribbean	23397	2216	3416	1736	31.5	1167	36.5	14862	63.5
32	Central America	248353	5756	11784	9974	11.1	8536	14.5	212303	85.5
		271750	7972	15200	11710	12.8	9703	16.4	227165	83.6
41	South America	1777573	72898	212371	157087	24.9	149107	33.3	1186110	66.7
51	Oceania	793540	17904	27179	18433	8.0	16673	10.1	713351	89.9
52	Polynesia	56118	209	766	670	2.9	3102	8.5	51371	91.5
		849658	18113	27945	19103	7.7	19775	10.0	764722	90.0
61	Eastern Africa	639474	18742	44145	52037	18.0	49451	25.7	475099	74.3
62	Middle Africa	657061	16291	74618	78276	25.7	76653	37.4	411223	62.6
63	Northern Africa	794112	8881	20477	13719	5.4	11037	6.8	739998	93.2
64	Southern Africa	266428	959	2528	3757	2.7	5731	4.9	253453	95.1
65	Western Africa	632996	12342	46048	34493	14.7	18898	17.7	521215	82.3
		2990071	57215	187816	182282	14.3	161770	19.7	2400988	80.3
71	Western Asia	432992	2240	2341	1824	1.5	3813	2.4	422774	97.6
81	Southeast. Asia	444483	9015	23723	23087	12.6	25334	18.3	363324	81.7
82	South Asia	671842	19066	41006	28898	13.2	26447	17.2	556425	82.8
84	East Asia	1112296	9619	23093	34349	6.0	39308	9.6	1005927	90.4
85	Central Asia	414363	1071	2279	1522	1.2	1623	1.6	407868	98.4
86	Japan	37178	445	1857	2561	13.1	3183	21.6	29132	78.4
		2680162	39216	91958	90417	8.3	95895	11.8	2362676	88.2
	DEVELOPING	8171488	179305	508595	441429	13.8	420207	19.0	6621952	81.0
	DEVELOPED	5228028	84395	221434	248744	10.6	257784	15.5	4415671	84.5
	WORLD TOTAL	13399516	263700	730029	690173	12.6	677991	17.6	11037623	82.4

Table A37 Gross extents with cultivation potential for rain-fed plus irrigated pulses (1000 ha) - intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	28812	80200	95227	9.6	68161	12.7	1866098	87.3
21	Eastern Europe	170952	18720	26991	25510	41.7	16529	51.3	83202	48.7
22	Northern Europe	172524	3408	9749	7095	11.7	4337	14.3	147935	85.7
23	Southern Europe	131643	4527	6496	5833	12.8	3314	15.3	111473	84.7
24	Western Europe	109547	8891	15816	12124	33.6	9473	42.3	63243	57.7
25	Russian Fed.	1674146	9113	59325	62724	7.8	38383	10.1	1504601	89.9
		2258812	44659	118377	113286	12.2	72036	15.4	1910454	84.6
31	Caribbean	23397	932	2636	2855	27.5	1830	35.3	15144	64.7
32	Central America	248353	5196	9313	11301	10.4	8929	14.0	213614	86.0
		271750	6128	11949	14156	11.9	10759	15.8	228758	84.2
41	South America	1777573	37439	91627	189935	17.9	171408	27.6	1287164	72.4
51	Oceania	793540	27138	24699	15400	8.5	12166	10.0	714137	90.0
52	Polynesia	56118	48	292	684	1.8	618	2.9	54476	97.1
		849658	27186	24991	16084	8.0	12784	9.5	768613	90.5
61	Eastern Africa	639474	30460	68429	75384	27.3	53618	35.6	411583	64.4
62	Middle Africa	657061	13472	41966	79850	20.6	75829	32.1	445944	67.9
63	Northern Africa	794112	19650	22032	13793	7.0	14069	8.8	724568	91.2
64	Southern Africa	266428	2159	4818	7037	5.3	9615	8.9	242799	91.1
65	Western Africa	632996	8456	45309	49962	16.4	44889	23.5	484380	76.5
		2990071	74197	182554	226026	16.1	198020	22.8	2309274	77.2
71	Western Asia	432992	3542	2790	1122	1.7	557	1.9	424981	98.1
81	Southeast. Asia	444483	1499	15902	21631	8.8	20480	13.4	384971	86.6
82	South Asia	671842	17508	68630	39813	18.7	24948	22.5	520943	77.5
84	East Asia	1112296	5380	26679	31931	5.8	34168	8.8	1014138	91.2
85	Central Asia	414363	702	3257	3290	1.7	2462	2.3	404652	97.7
86	Japan	37178	496	2237	3092	15.7	2970	23.7	28383	76.3
		2680162	25585	116705	99757	9.0	85028	12.2	2353087	87.8
	DEVELOPING	8171488	146443	403680	528588	13.2	463420	18.9	6629357	81.1
	DEVELOPED	5228028	101105	225513	227005	10.6	155333	13.6	4519072	86.4
	WORLD TOTAL	13399516	247548	629193	755593	12.2	618753	16.8	11148429	83.2

Table A38 Gross extents with cultivation potential for rain-fed plus irrigated oil crops (1000 ha) - intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	33879	101981	132872	12.6	75288	16.1	1794478	83.9
21	Eastern Europe	170952	22850	30530	29682	48.6	26873	64.3	61017	35.7
22	Northern Europe	172524	6135	10167	10591	15.6	9332	21.0	136299	79.0
23	Southern Europe	131643	6891	14340	15447	27.9	14114	38.6	80851	61.4
24	Western Europe	109547	9439	17601	17429	40.6	14078	53.4	51000	46.6
25	Russian Fed.	1674146	27819	53363	48590	7.8	63068	11.5	1481306	88.5
		2258812	73134	126001	121739	14.2	127465	19.8	1810473	80.2
31	Caribbean	23397	1473	3139	2290	29.5	1904	37.6	14591	62.4
32	Central America	248353	9118	11384	12268	13.2	10071	17.3	205512	82.7
		271750	10591	14523	14558	14.6	11975	19.0	220103	81.0
41	South America	1777573	78891	224299	220965	29.5	156604	38.3	1096814	61.7
51	Oceania	793540	31570	34807	29412	12.1	27550	15.5	670201	84.5
52	Polynesia	56118	562	2841	5115	15.2	2275	19.2	45325	80.8
		849658	32132	37648	34527	12.3	29825	15.8	715526	84.2
61	Eastern Africa	639474	40864	91202	70883	31.7	47760	39.2	388765	60.8
62	Middle Africa	657061	25145	98798	80954	31.2	76373	42.8	375791	57.2
63	Northern Africa	794112	21715	31430	22283	9.5	20073	12.0	698611	88.0
64	Southern Africa	266428	1904	7800	12181	8.2	14902	13.8	229641	86.2
65	Western Africa	632996	18551	63375	51838	21.1	48656	28.8	450576	71.2
		2990071	108179	292605	238139	21.4	207764	28.3	2143384	71.7
71	Western Asia	432992	5352	6893	7117	4.5	7330	6.2	406300	93.8
81	Southeast. Asia	444483	9521	30655	37840	17.6	27100	23.6	339367	76.4
82	South Asia	671842	31583	68619	43192	21.3	25678	25.2	502770	74.8
84	East Asia	1112296	11857	20072	29172	5.5	37693	8.9	1013502	91.1
85	Central Asia	414363	3054	3952	2183	2.2	3568	3.1	401606	96.9
86	Japan	37178	872	2939	3220	18.9	3233	27.6	26914	72.4
		2680162	56887	126237	115607	11.1	97272	14.8	2284159	85.2
	DEVELOPING	8171488	259590	664459	598281	18.6	479987	24.5	6169171	75.5
	DEVELOPED	5228028	139455	265728	287243	13.2	233536	17.7	4302066	82.3
	WORLD TOTAL	13399516	399045	930187	885524	16.5	713523	21.9	10471237	78.1

Table A39 Gross extents with cultivation potential for rain-fed plus irrigated sugar crops (1000 ha) - intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	31432	80918	73291	8.7	47509	10.9	1905348	89.1
21	Eastern Europe	170952	9361	22721	17894	29.2	11779	36.1	109197	63.9
22	Northern Europe	172524	387	6062	9157	9.0	9622	14.6	147296	85.4
23	Southern Europe	131643	4758	7547	6588	14.4	4261	17.6	108489	82.4
24	Western Europe	109547	9354	15579	9643	31.6	5845	36.9	69126	63.1
25	Russian Fed.	1674146	1440	6648	33215	2.5	61427	6.1	1571416	93.9
		2258812	25300	58557	76497	7.1	92934	11.2	2005524	88.8
31	Caribbean	23397	2037	2567	1870	27.7	1442	33.8	15481	66.2
32	Central America	248353	3011	8772	8066	8.0	5644	10.3	222860	89.7
		271750	5048	11339	9936	9.7	7086	12.3	238341	87.7
41	South America	1777573	47382	106251	186298	19.1	157627	28.0	1280015	72.0
51	Oceania	793540	27159	26984	14966	8.7	9274	9.9	715157	90.1
52	Polynesia	56118	135	828	2680	6.5	4829	15.1	47646	84.9
		849658	27294	27812	17646	8.6	14103	10.2	762803	89.8
61	Eastern Africa	639474	11303	22487	17539	8.0	17355	10.7	570790	89.3
62	Middle Africa	657061	9782	65122	52479	19.4	38992	25.3	490686	74.7
63	Northern Africa	794112	8017	11443	10543	3.8	8418	4.8	755691	95.2
64	Southern Africa	266428	468	1799	1630	1.5	1778	2.1	260753	97.9
65	Western Africa	632996	3512	15266	17724	5.8	20853	9.1	575641	90.9
		2990071	33082	116117	99915	8.3	87396	11.3	2653561	88.7
71	Western Asia	432992	2931	2982	1455	1.7	1294	2.0	424330	98.0
81	Southeast. Asia	444483	2298	12101	28859	9.7	37842	18.2	363383	81.8
82	South Asia	671842	17747	35683	20265	11.0	10921	12.6	587226	87.4
84	East Asia	1112296	7767	16953	21974	4.2	25747	6.5	1039855	93.5
85	Central Asia	414363	1700	2157	1068	1.2	655	1.3	408783	98.7
86	Japan	37178	854	2325	2755	16.0	2797	23.5	28447	76.5
		2680162	30366	69219	74921	6.5	77962	9.4	2427694	90.6
	DEVELOPING	8171488	118090	304411	372450	9.7	333397	13.8	7043140	86.2
	DEVELOPED	5228028	84745	168784	167509	8.1	152514	11.0	4654476	89.0
	WORLD TOTAL	13399516	202835	473195	539959	9.1	485911	12.7	11697616	87.3

Table A40 Gross extents with cultivation potential for rain-fed plus irrigated cotton (1000 ha) - intermediate input level

REGION	NAME	TOTAL	VS	S	MS	%VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	7440	10451	9394	1.3	19904	2.2	2091309	97.8
21	Eastern Europe	170952	0	7	7	0.0	17	0.0	170921	100.0
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	341	883	422	1.3	259	1.4	129738	98.6
24	Western Europe	109547	0	76	30	0.1	0	0.1	109441	99.9
25	Russian Fed.	1674146	0	356	316	0.0	36	0.0	1673438	100.0
		2258812	341	1322	775	0.1	312	0.1	2256062	99.9
31	Caribbean	23397	18	409	1699	9.1	2835	21.2	18436	78.8
32	Central America	248353	2689	4261	6051	5.2	7113	8.1	228239	91.9
		271750	2707	4670	7750	5.6	9948	9.2	246675	90.8
41	South America	1777573	14309	39598	59206	6.4	109242	12.5	1555218	87.5
51	Oceania	793540	22408	26104	14051	7.9	8027	8.9	722950	91.1
52	Polynesia	56118	63	78	210	0.6	302	1.2	55465	98.8
		849658	22471	26182	14261	7.4	8329	8.4	778415	91.6
61	Eastern Africa	639474	20122	48859	54235	19.3	50933	27.2	465325	72.8
62	Middle Africa	657061	8000	18603	27070	8.2	44484	14.9	558904	85.1
63	Northern Africa	794112	18721	21934	14331	6.9	15048	8.8	724078	91.2
64	Southern Africa	266428	840	1255	2590	1.8	5995	4.0	255748	96.0
65	Western Africa	632996	8550	31535	33271	11.6	32342	16.7	527298	83.3
		2990071	56233	122186	131497	10.4	148802	15.3	2531353	84.7
71	Western Asia	432992	3093	1532	422	1.2	395	1.3	427550	98.7
81	Southeast. Asia	444483	304	1079	7946	2.1	14822	5.4	420332	94.6
82	South Asia	671842	33310	61958	48004	21.3	23927	24.9	504643	75.1
84	East Asia	1112296	4103	3234	1679	0.8	7198	1.5	1096082	98.5
85	Central Asia	414363	370	844	672	0.5	266	0.5	412211	99.5
86	Japan	37178	0	0	0	0.0	278	0.7	36900	99.3
		2680162	38087	67115	58301	6.1	46491	7.8	2470168	92.2
	DEVELOPING	8171488	114492	235179	257386	7.4	314902	11.3	7249529	88.7
	DEVELOPED	5228028	30189	37877	24220	1.8	28521	2.3	5107221	97.7
	WORLD TOTAL	13399516	144681	273056	281606	5.2	343423	7.8	12356750	92.2

Table A41 Gross extents with cultivation potential for rain-fed plus irrigated cereals (1000ha) - high input level

REGION	NAME	TOTAL ⁴⁰	VS	S	MS	% VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	133718	122906	60465	14.8	34387	16.4	1787022	83.6
21	Eastern Europe	170952	31700	38375	28766	57.8	15855	67.1	56256	32.9
22	Northern Europe	172524	9638	18462	12833	23.7	9058	29.0	122533	71.0
23	Southern Europe	131643	10430	7671	4825	17.4	2354	19.2	106363	80.8
24	Western Europe	109547	23004	16921	10484	46.0	5599	51.1	53539	48.9
25	Russian Fed.	1674146	45141	80934	75006	12.0	39977	14.4	1433088	85.6
		2258812	119913	162363	131914	18.3	72843	21.6	1771779	78.4
31	Caribbean	23397	4607	3246	1292	39.1	550	41.4	13702	58.6
32	Central America	248353	15577	16613	8940	16.6	3009	17.8	204214	82.2
		271750	20184	19859	10232	18.5	3559	19.8	217916	80.2
41	South America	1777573	246217	293796	174822	40.2	122409	47.1	940329	52.9
51	Oceania	793540	56657	34627	18609	13.8	8985	15.0	674662	85.0
52	Polynesia	56118	1088	2310	4235	13.6	7481	26.9	41004	73.1
		849658	57745	36937	22844	13.8	16466	15.8	715666	84.2
61	Eastern Africa	639474	86668	83072	54215	35.0	19895	38.1	395624	61.9
62	Middle Africa	657061	104328	117470	69523	44.3	22814	47.8	342926	52.2
63	Northern Africa	794112	64138	28512	11671	13.1	5290	13.8	684501	86.2
64	Southern Africa	266428	6529	5046	4093	5.9	1961	6.6	248799	93.4
65	Western Africa	632996	65857	78010	43276	29.6	18620	32.5	427233	67.5
		2990071	327520	312110	182778	27.5	68580	29.8	2099083	70.2
71	Western Asia	432992	8513	6549	5205	4.7	2747	5.3	409978	94.7
81	Southeast. Asia	444483	38008	50580	28818	26.4	32480	33.7	294597	66.3
82	South Asia	671842	109688	67843	26996	30.4	7214	31.5	460101	68.5
84	East Asia	1112296	51432	47990	29364	11.6	12870	12.7	970640	87.3
85	Central Asia	414363	9657	6760	5074	5.2	2527	5.8	390345	94.2
86	Japan	37178	2871	2415	1349	17.8	744	19.8	29799	80.2
		2680162	211656	175588	91601	17.9	55835	19.9	2145482	80.1
	DEVELOPING	8171488	812307	807797	467524	25.5	259867	28.7	5823993	71.3
	DEVELOPED	5228028	313159	322311	212337	16.2	116959	18.5	4263262	81.5
	WORLD TOTAL	13399516	1125466	1130108	679861	21.9	376826	24.7	10087255	75.3

⁴⁰ Total extent derived from digital version of the Soil Map of the World (FAO, 1995c).

Table A42 Gross extents with cultivation potential for rain-fed plus irrigated roots & tubers (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	29224	83081	100299	9.9	85834	14.0	1840060	86.0
21	Eastern Europe	170952	9356	30767	31524	41.9	13112	49.6	86193	50.4
22	Northern Europe	172524	2455	7785	9740	11.6	9186	16.9	143358	83.1
23	Southern Europe	131643	2921	4805	5625	10.1	4370	13.5	113922	86.5
24	Western Europe	109547	3195	9303	13437	23.7	11060	33.8	72552	66.2
25	Russian Fed.	1674146	11392	81661	65191	9.5	32416	11.4	1483486	88.6
		2258812	29319	134321	125517	12.8	70144	15.9	1899511	84.1
31	Caribbean	23397	4200	3278	1279	37.4	638	40.2	14002	59.8
32	Central America	248353	12689	15575	8756	14.9	5314	17.0	206019	83.0
		271750	16889	18853	10035	16.8	5952	19.0	220021	81.0
41	South America	1777573	193105	217596	147801	31.4	158437	40.3	1060634	59.7
51	Oceania	793540	21876	34429	16530	9.2	10873	10.5	709832	89.5
52	Polynesia	56118	952	546	1470	5.3	9377	22.0	43773	78.0
		849658	22828	34975	18000	8.9	20250	11.3	753605	88.7
61	Eastern Africa	639474	43254	60704	49780	24.0	33562	29.3	452174	70.7
62	Middle Africa	657061	66822	92819	88929	37.8	81617	50.3	326874	49.7
63	Northern Africa	794112	25689	36565	15943	9.8	8749	10.9	707166	89.1
64	Southern Africa	266428	5058	1691	1139	3.0	1140	3.4	257400	96.6
65	Western Africa	632996	39369	57462	31433	20.3	14480	22.6	490252	77.4
		2990071	180192	249241	187224	20.6	139548	25.3	2233866	74.7
71	Western Asia	432992	4067	4546	1406	2.3	400	2.4	422573	97.6
81	Southeast. Asia	444483	46474	32427	26472	23.7	41743	33.1	297367	66.9
82	South Asia	671842	41083	59752	36094	20.4	29522	24.8	505391	75.2
84	East Asia	1112296	15859	35809	34352	7.7	28610	10.3	997666	89.7
85	Central Asia	414363	2482	7167	1210	2.6	216	2.7	403288	97.3
86	Japan	37178	981	1643	1406	10.8	2235	16.9	30913	83.1
		2680162	106879	136798	99534	12.8	102326	16.6	2234625	83.4
	DEVELOPING	8171488	501103	625937	446064	19.3	413805	24.3	6184579	75.7
	DEVELOPED	5228028	81400	253474	243752	11.1	169086	14.3	4480316	85.7
	WORLD TOTAL	13399516	582503	879411	689816	16.1	582891	20.4	10664895	79.6

Table A43 Gross extents with cultivation potential for rain-fed plus irrigated pulses (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	51804	105813	67649	10.5	21936	11.6	1891296	88.4
21	Eastern Europe	170952	21160	21545	9713	30.7	825	31.1	117709	68.9
22	Northern Europe	172524	2423	8381	3724	8.4	1149	9.1	156847	90.9
23	Southern Europe	131643	5286	6762	1629	10.4	571	10.8	117395	89.2
24	Western Europe	109547	11540	10910	3270	23.5	609	24.0	83218	76.0
25	Russian Fed.	1674146	10717	66749	28447	6.3	3259	6.5	1564974	93.5
		2258812	51126	114347	46783	9.4	6413	9.7	2040143	90.3
31	Caribbean	23397	1546	3203	2533	31.1	1617	38.0	14498	62.0
32	Central America	248353	8926	12364	10248	12.7	7591	15.8	209224	84.2
		271750	10472	15567	12781	14.3	9208	17.7	223722	82.3
41	South America	1777573	57083	166909	216538	24.8	172698	34.5	1164345	65.5
51	Oceania	793540	32368	31241	14417	9.8	7141	10.7	708373	89.3
52	Polynesia	56118	117	693	645	2.6	3353	8.6	51310	91.4
		849658	32485	31934	15062	9.4	10494	10.6	759683	89.4
61	Eastern Africa	639474	73153	76080	52769	31.6	32675	36.7	404797	63.3
62	Middle Africa	657061	43975	75421	82921	30.8	91154	44.7	363590	55.3
63	Northern Africa	794112	43551	32202	12569	11.1	8077	12.1	697713	87.9
64	Southern Africa	266428	5377	2153	2389	3.7	3888	5.2	252621	94.8
65	Western Africa	632996	38931	58899	47964	23.0	34272	28.4	452930	71.6
		2990071	204987	244755	198612	21.7	170066	27.4	2171651	72.6
71	Western Asia	432992	5717	4532	822	2.6	56	2.6	421865	97.4
81	Southeast. Asia	444483	16986	37719	24413	17.8	30629	24.7	334736	75.3
82	South Asia	671842	27482	99578	56141	27.3	14910	29.5	473731	70.5
84	East Asia	1112296	12267	51950	33582	8.8	23433	10.9	991064	89.1
85	Central Asia	414363	3997	6417	2826	3.2	244	3.3	400879	96.7
86	Japan	37178	1327	2853	1842	16.2	1008	18.9	30148	81.1
		2680162	62059	198517	118804	14.2	70224	16.8	2230558	83.2
	DEVELOPING	8171488	339108	628120	546360	18.5	424597	23.7	6233303	76.3
	DEVELOPED	5228028	136625	254254	130691	10.0	36498	10.7	4669960	89.3
	WORLD TOTAL	13399516	475733	882374	677051	15.2	461095	18.6	10903263	81.4

Table A44 Gross extents with cultivation potential for rain-fed plus irrigated oil crops (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	55640	96295	99129	11.7	64292	14.7	1823142	85.3
21	Eastern Europe	170952	22320	24825	26882	43.3	19677	54.8	77248	45.2
22	Northern Europe	172524	4050	12157	11847	16.3	8820	21.4	135650	78.6
23	Southern Europe	131643	6223	9674	5836	16.5	5011	20.3	104899	79.7
24	Western Europe	109547	11436	11965	13479	33.7	6380	39.5	66287	60.5
25	Russian Fed.	1674146	32194	45724	36656	6.8	63464	10.6	1496108	89.4
		2258812	76223	104345	94700	12.2	103352	16.8	1880192	83.2
31	Caribbean	23397	2651	2411	2656	33.0	1651	40.0	14028	60.0
32	Central America	248353	16993	11681	8234	14.9	7410	17.8	204035	82.2
		271750	19644	14092	10890	16.4	9061	19.8	218063	80.2
41	South America	1777573	219467	315166	190659	40.8	144326	48.9	907955	51.1
51	Oceania	793540	39312	37353	23855	12.7	16386	14.7	676634	85.3
52	Polynesia	56118	7469	3365	2843	24.4	2575	29.0	39866	71.0
		849658	46781	40718	26698	13.4	18961	15.7	716500	84.3
61	Eastern Africa	639474	88742	92533	41987	34.9	23778	38.6	392434	61.4
62	Middle Africa	657061	105610	125006	85252	48.1	62890	57.6	278303	42.4
63	Northern Africa	794112	44680	35965	16628	12.2	11494	13.7	685345	86.3
64	Southern Africa	266428	5821	2991	5284	5.3	5556	7.4	246776	92.6
65	Western Africa	632996	66895	59767	45594	27.2	33618	32.5	427122	67.5
		2990071	311748	316262	194745	27.5	137336	32.1	2029980	67.9
71	Western Asia	432992	7691	5600	3408	3.9	3311	4.6	412982	95.4
81	Southeast. Asia	444483	58578	44224	38449	31.8	23409	37.0	279823	63.0
82	South Asia	671842	57465	94545	47885	29.8	15152	32.0	456795	68.0
84	East Asia	1112296	29765	30005	31619	8.2	25941	10.5	994966	89.5
85	Central Asia	414363	8726	4317	1004	3.4	1368	3.7	398948	96.3
86	Japan	37178	1842	2369	1685	15.9	1327	19.4	29955	80.6
		2680162	156376	175460	120642	16.9	67197	19.4	2160487	80.6
	DEVELOPING	8171488	720553	827576	521502	25.3	362479	29.8	5739378	70.2
	DEVELOPED	5228028	173017	240362	219369	12.1	185357	15.6	4409923	84.4
	WORLD TOTAL	13399516	893570	1067938	740871	20.2	547836	24.3	10149301	75.7

Table A45 Gross extents with cultivation potential for rain-fed plus irrigated sugar crops (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	51010	69488	47007	7.8	27276	9.1	1943717	90.9
21	Eastern Europe	170952	13882	11822	3345	17.0	312	17.2	141591	82.8
22	Northern Europe	172524	27	4350	5745	5.9	4390	8.4	158012	91.6
23	Southern Europe	131643	5431	5651	2427	10.3	579	10.7	117555	89.3
24	Western Europe	109547	8791	9780	3020	19.7	261	19.9	87695	80.1
25	Russian Fed.	1674146	3366	10055	15087	1.7	37086	3.9	1608552	96.1
		2258812	31497	41658	29624	4.6	42628	6.4	2113405	93.6
31	Caribbean	23397	3956	2138	1855	34.0	594	36.5	14854	63.5
32	Central America	248353	9083	12077	6525	11.1	4301	12.9	216367	87.1
		271750	13039	14215	8380	13.1	4895	14.9	231221	85.1
41	South America	1777573	79295	167301	273659	29.3	201086	40.6	1056232	59.4
51	Oceania	793540	35619	23750	10768	8.8	5529	9.5	717874	90.5
52	Polynesia	56118	537	4065	6719	20.2	4357	27.9	40440	72.1
		849658	36156	27815	17487	9.6	9886	10.8	758314	89.2
61	Eastern Africa	639474	29639	27919	17546	11.7	24698	15.6	539672	84.4
62	Middle Africa	657061	58551	96778	67643	33.9	56493	42.5	377596	57.5
63	Northern Africa	794112	19446	23338	8901	6.5	13262	8.2	729165	91.8
64	Southern Africa	266428	3531	2394	828	2.5	189	2.6	259486	97.4
65	Western Africa	632996	16340	21067	25599	10.0	29055	14.5	540935	85.5
		2990071	127507	171496	120517	14.0	123697	18.2	2446854	81.8
71	Western Asia	432992	5438	4875	1360	2.7	190	2.7	421129	97.3
81	Southeast. Asia	444483	7651	38744	51769	22.1	42996	31.8	303323	68.2
82	South Asia	671842	33324	47740	17048	14.6	14577	16.8	559153	83.2
84	East Asia	1112296	18279	37010	33916	8.0	18719	9.7	1004372	90.3
85	Central Asia	414363	5603	4613	835	2.7	198	2.7	403114	97.3
86	Japan	37178	1404	2460	2154	16.2	1055	19.0	30105	81.0
		2680162	66261	130567	105722	11.3	77545	14.2	2300067	85.8
	DEVELOPING	8171488	290673	490059	514203	15.8	410715	20.9	6465838	79.1
	DEVELOPED	5228028	119530	137356	89553	6.6	76488	8.1	4805101	91.9
	WORLD TOTAL	13399516	410203	627415	603756	12.2	487203	15.9	11270939	84.1

Table A46 Gross extents with cultivation potential for rain-fed plus irrigated cotton (1000ha) - high input level

REGION	NAME	TOTAL	VS	S	MS	% VS+S+MS	mS	% VS+S+MS+mS	NS	% NS
11	North America	2138498	11400	13219	10040	1.6	6686	1.9	2097153	98.1
21	Eastern Europe	170952	0	15	13	0.0	0	0.0	170924	100.0
22	Northern Europe	172524	0	0	0	0.0	0	0.0	172524	100.0
23	Southern Europe	131643	534	1066	446	1.6	0	1.6	129597	98.4
24	Western Europe	109547	0	110	51	0.1	0	0.1	109386	99.9
25	Russian Fed.	1674146	0	720	761	0.1	0	0.1	1672665	99.9
		2258812	534	1911	1271	0.2	0	0.2	2255096	99.8
31	Caribbean	23397	64	286	2107	10.5	3541	25.6	17399	74.4
32	Central America	248353	5047	5632	4868	6.3	6953	9.1	225853	90.9
		271750	5111	5918	6975	6.6	10494	10.5	243252	89.5
41	South America	1777573	25006	45814	67822	7.8	135715	15.4	1503216	84.6
51	Oceania	793540	31204	24605	11959	8.5	4977	9.2	720795	90.8
52	Polynesia	56118	90	86	315	0.9	440	1.7	55187	98.3
		849658	31294	24691	12274	8.0	5417	8.7	775982	91.3
61	Eastern Africa	639474	44230	63146	51314	24.8	31134	29.7	449650	70.3
62	Middle Africa	657061	20417	28153	40170	13.5	52109	21.4	516212	78.6
63	Northern Africa	794112	39385	31995	11627	10.5	9861	11.7	701244	88.3
64	Southern Africa	266428	1720	4687	1232	2.9	948	3.2	257841	96.8
65	Western Africa	632996	25471	47646	36550	17.3	34271	22.7	489058	77.3
		2990071	131223	175627	140893	15.0	128323	19.3	2414005	80.7
71	Western Asia	432992	6022	2757	379	2.1	0	2.1	423834	97.9
81	Southeast. Asia	444483	590	3508	22690	6.0	35996	14.1	381699	85.9
82	South Asia	671842	59282	83075	40027	27.1	16230	29.6	473228	70.4
84	East Asia	1112296	7264	7193	5954	1.8	12833	3.0	1079052	97.0
85	Central Asia	414363	798	3108	2303	1.5	0	1.5	408154	98.5
86	Japan	37178	0	0	0	0.0	1152	3.1	36026	96.9
		2680162	67934	96884	70974	8.8	66211	11.3	2378159	88.7
	DEVELOPING	8171488	235386	327086	287358	10.4	340031	14.6	6981627	85.4
	DEVELOPED	5228028	43138	39735	23270	2.0	12815	2.3	5109070	97.7
	WORLD TOTAL	13399516	278524	366821	310628	7.1	352846	9.8	12090697	90.2

APPENDIX II

PROCEDURES FOR COMPILATION OF THE TERRAIN SLOPES DATABASE

The GTOPO30 database (EROS Data Center, 1998) provides digital elevation data in a regular grid of 30 arc-seconds latitude/longitude. A distribution of terrain slope classes for each 5 arc-min grid-cell of the Digital Soil Map of the World (DSMW) has subsequently been derived from the 30 arc-second DEM and the DSMW as follows:

1. Calculation of ‘quadrant’ slope classes for each 30 arc-second grid-cell of GTOPO30 using 7 classes: 0-2%, 2-5%, 5-8%, 8-16%, 16-30%, 30-45%, and > 45%. Since the computation of mathematical slope angles from 30 arc-second grid-cells gives unrealistic results, exaggerating the prevalence of flat terrain, the following rule-based procedures have been applied:
 - 1a Determine for each 3 by 3 sub-grid the difference in altitude of the central grid-cell with regard to all neighboring grid-cells, e.g., $Alt(a) - Alt(e)$, $Alt(b) - Alt(e)$, etc.
 - 1b Select the orthogonal pair defined by the neighboring grid-cell with the largest altitude difference, i.e., a-e-i, c-e-g or b-e-h, d-e-f.

a	b	c
d	e	f
g	h	i

- 1c For the selected orthogonal pair of neighboring grid-cells and corresponding altitude differences $dAlt_j$, $j=1, \dots, 4$, determine ‘quadrant’ slope classes according to specified ranges of elevation differences. The following thresholds were used for classification of terrain conditions in the Global AEZ study: $\leq 2m$, 6m, 16m, 40m, 125m, 250m, and $> 250m$
2. Aggregation of the ‘quadrant’ slope classes by 30 arc-second respectively to: 5 arc-min latitude/longitude grid-cells of the DSMW, and to individual soil association map units.
3. Establishing ‘priority’ soil unit/slope relationships by defining upper limits of slope classes for each soil unit. For use in GAEZ, the soil units have been allocated to five groups with regard to maximum slopes of respectively 2% (max. 8%), 8% (max. 16%), 30%, 30-45%, and one unlimited class. For instance, it is known that the major part of the Fluvisols are related to the flat slopes (0-2%). This approach was first elaborated in South East Asia (Bruggeman and Nachtergaele, 1986) and was further refined by Sys (Sys, 1990) for China. The approach was also used for FAO’s study on World Agriculture: Towards 2010 (FAO, 1995d). In GAEZ the five groups of soils for priority slope classes are defined as follows:

CLASS	FAO '74	FAO '90
Class 1	< 2% / max. 8%: all J, G, O soils; all gleyic soil units (Zg, Sg, Hg, Mg, Bg, Lg, Dg, Pg, Ag), and miscellaneous land units ST, WR, WRs	< 2% / max. 8%: all FL, GL, HS soils; ATc, all gleyic soil units, and miscellaneous land units ST, WR, WRs
Class 2	< 8% / max. 16%: all S, Z soils (except for gleyic units)	< 8% / max. 16%: all SN, SC soils (except for gleyic units); and all stagno-gleyic soil units
Class 3	< 30%: all A, Q, M, L, N, D, V soils (except for gleyic units) and all luvic soil units (Ql, Yl, Xl, Kl, Cl, Hl)	< 30%: all AC, AL, AR, GR, LV, LX, NT, PD, VR soils (except for gleyic and stagno-gleyic units); ATa and all luvic soil units
Class 4	< 30-45%: all C, E, X, Y, F, K, H, W, P soils (except for gleyic and luvic soil units); and miscellaneous unit DS	<30-45%: all CH, CL, GY, FR, KS, PH, PL, PZ soils (except for gleyic, stagno-gleyic and luvic soil units); and misc. unit DS
Class 5	all slopes: all T, B, I, R, U soils; (except for gleyic and luvic soil units); and miscellaneous units RK and GLR	all slopes: all AN, CM, LP, RG soils; ATf, ATu (except for gleyic, stagno-gleyic and luvic soil units); and miscellaneous units RK and GLR

4. Establishing for each soil association map unit of the DSMW a consistent allocation of slope classes and soil units, accounting for:
 - slope distribution calculated in step 2 above by grid-cell and soil association map unit.
 - Slope classes as defined for the soil units in the soil association map unit expansion table of the DSMW.
 - the 'priority' slope relationships (as defined in 3 above).
5. Allocation of soil units within soil association map units to 5 min grid-cells, according to calculated slope distributions, slope 'priorities', and soil association map unit composition.

APPENDIX III

1. SOIL AND TERRAIN CONSTRAINT CLASSIFICATIONS FOR SOIL UNITS ACCORDING TO FAO'74 LEGEND

TERRAIN SLOPE CONSTRAINTS

	Rain-fed	Gravity irrigation*	Sprinkler irrigation
Severe constraints	slopes > 30%	slopes > 8%	slopes > 16%
Constraints	slopes 16-30%	slopes 5-8%	slopes 8-16%
Slight constraints	slopes 8-16%	slopes 2-5%	slopes 5-8%
No constraints	slopes 0-8%	slopes 0-2%	slopes 0-5%

* Applicable to non-terraced land

SOIL DEPTH CONSTRAINTS

Severe constraints: All soils with depth limitations within 50 cm of the surface caused by the presence of coherent hardrock or hard-pans (shallow soils): Lithosols (I), Renzinas (E), Rankers (U), all soils with Lithic phase.

Constraints: All soils with depth limitations within 100 cm of the surface by presence of Petrocalcic, Petrogypsic, Petroferric and Duripan phases.

No constraints: Deep soils: all other soils.

NATURAL FERTILITY CONSTRAINTS

Severe constraints: Soils with low natural fertility and soils where a major land improvement is required before cultivation is possible: all other soils.

Constraints: Soils with moderate natural fertility: Jd, Gh, Gd, Rd, Q, Qc, Ql, T, To, Th, Xy, M, Mo, Mg, Bc, Bd, Bh, Bg, Bf, Lf, Lp, Lc, Lg, D, De, Dg, Pl, W, We, Wh, A, Ao, Ah, Nd, Nh, Fr and Fh.

No constraints: Soils with high natural fertility: J, Je, G, Ge, Gc, Gm, R, Re, Rc, E, Tm, V, VP, Vc, Sm, Y, Yh, Yk, Yl, X, Xh, Xk, Xl, K, Kh, Kk, Kl, C, Ch, Ck, Cl, Cg, H, Hh, Hc, Hl, Hg, B, Be, Bk, Bv, L, Lo, Lk, Lv, Wm, N and Ne.

SOIL DRAINAGE CONSTRAINTS

Severe constraints: Poorly and imperfectly drained soils: All Gleysols (G, Ge, Gc, Gd, Gm, Gh, Gp and Gx), all Planosols (W, We, Wd, Wm, Wh, Ws, Wx) and all gleyic sub-groups (Zg, Sg, Mg, Hg, Lg, Dg, Pg and Ag), except Bg.

No constraints: Excessively and well drained soils: all other soils.

SOIL TEXTURE CONSTRAINTS

Severe constraints: Coarse textured soils. Soils with less than 18% clay, more than 65% sand, or which have stones, boulders or rock outcrops in the surface

layer or at the surface: All Arenosols (Q, Qc, Ql, Qf, Qa), all Regosols (R, Re, Rc, Rd, Rx) and Vitric Andosols (Tv) with coarse texture, and all soils with petric and stony phase.

Constraints Soils with heavy cracking clays: Soils with 30% or more clay to at least 50 cm deep, with cracks at least 1 cm wide and 50 cm deep at some period in most years (unless irrigated), and high bulk density between the cracks: All Vertisols (V, Vp, Vc) and vertic sub-groups (Bv and Lv).

No constraints: Soils with medium and fine textures: all other soils.

SOIL CHEMICAL CONSTRAINTS

Severe constraints: Soils with severe salinity, sodicity, or gypsum limitations.

- (a) Soils with a high salt content or exchangeable sodium saturation within 100 cm of the surface: All Solonchaks (Z, Zo, Zm, Zt, Zg), all Solonetz (S, So, Sm, Sg) and Solodic Planosols (Ws);
- (b) Soils with gypsic horizons: Gypsic Xerosols (Xy), Gypsic Yermosols (Yy);
- (c) Soils with saline and sodic phases.

No constraints: All other soils.

MICELLANEOUS LAND UNITS

The miscellaneous land units of the DSMW are considered as **severe constraints**. They include: dunes, shifting sands, salt flats, rock debris, desert detritus, glaciers and snow caps.

2. SOIL AND TERRAIN CONSTRAINT CLASSIFICATIONS FOR SOIL UNITS ACCORDING TO FAO'90 REVISED LEGEND

TERRAIN SLOPE CONSTRAINTS

	Rain-fed	Gravity irrigation *	Sprinkler irrigation
Severe constraints	slopes > 30%	slopes > 8%	slopes > 16%
Constraints	slopes 16-30%	slopes 5-8%	slopes 8-16%
Slight constraints	slopes 8-16%	slopes 2-5%	slopes 5-8%
No constraints	slopes 0-8%	slopes 0-2%	slopes 0-5%

* Applicable to non-terraced land

SOIL DEPTH CONSTRAINTS

Severe constraints: All soils with depth limitations within 50 cm of the surface caused by the presence of coherent hardrock or hard-pans (shallow soils): Leptosols (LP), all soils with Lithic phase

Constraints: All soils with depth limitations within 100 cm of the surface by presence of Petroferric and Duripan phases.

No constraints: Deep soils: all other soils

NATURAL FERTILITY CONSTRAINTS

No constraints: Soils with high natural fertility: FL, FLe, FLc, FLm, FLu, GL, GLe, GLk, GLa, GLm, GLu, RG, RGe, RGc, Rgu, AN, ANm, ANh, ANu, VR, VRe, VRk, CM, CMe, CMu, CMc, CMx, CMv, KS, KSh, KSl, KSk, CH, CHh, CHk, CHl, CHw, PH, PHh, PHc, PHl, GR, GRh, LV, LVh, LVx, LVk, LVv, PD, PDe, NT, NTh, NTr, AT, ATa, Atc.

Constraints: Soils with moderate natural fertility: FLd, FLs, GLd, RGd, AR, ARh, ARb, ARl, ARc, ARg, ANg, VRd, CMd, CMg, CMo, CL, CLh, CLl, CHg, PHg, PHj, GRg, LVf, LVa, LVg, LVj, PL, PLe, PLd, PLm, PLu, PDD, PDg, PDj, PZ, PZh, LX, LXh, AC, ACh, ACu, NTu, FR, FRh, FRr, FRu, HS, HSl, HSs, HSf, ATf.

Severe constraints: Soils with low natural fertility and soils where a major land improvement is required before cultivation is possible: all other soils.

SOIL DRAINAGE CONSTRAINTS

Severe constraints: Poorly and imperfectly drained soils: All Gleysols (GL, GLe, GLk, GLd, GLa, GLm, Glu, GLt, GLi), all planosols (PL, PLe, PLd, PLm, PLu, PLi) and soils with antraquic phases.

Constraints All soil with gleyic and stagnogleyic subgroups (ARg, ANg, CMg, SNg, SNj, SCg, CHg, PHg, PHj, GRg, LVg, LVj, PDg, PDj, PZg, LXg, LXj, ACg, ALg, ALj).

No constraints: Excessively and well drained soils: all other soils.

SOIL TEXTURE CONSTRAINTS

Severe constraints: Coarse textured soils, soils with less than 18% clay, more than 65% sand, or have stones, boulders or rock outcrops in the surface layer or at the surface: All Arenosols (AR, ARh, ARb, Arl, ARo, ARa, ARc, ARg), all Regosols (RG, RGe, RGc, RGy, RGd, RGu, RGi), all Podzols (PZ, PZh, PZb, PZf, PZc, PZg, PZi) and Vitric Andosols (ANz) with texture “1”, and soils with skeletal, yermic, rudic, desert and Gobi phases.

Constraints Soils with heavy cracking clays: Soils with 30% or more clay to at least 50 cm deep, with cracks at least 1 cm wide and 50 cm deep at some period in most years (unless irrigated), and high bulk density between the cracks: All Vertisols (VR, VRe, VRd, VRk, VRy) and vertic sub-groups (CMv, LVv).

No constraints: Soils with medium and fine textures: all other soils.

SOIL CHEMICAL CONSTRAINTS

Severe constraints: Soils with severe salinity, sodicity, or gypsum limitations:

- (a) Soils with a high salt content or exchangeable sodium saturation within 100 cm of the surface: All Solonchaks (SC, SCh, SCm, SCk, SCy, SCn, SCg, SCi), all Solonetz (SN, SNh, SNm, SNk, SNy, SNj, SNg) and Salic Fluvisols (FLs);
- (b) All Gypsisols (GY, GYh, GYk, GYl, GYp) and soils with gypsic horizons: (RGy, VRy, SNy, SCy, Ksy);
- (c) Soils with salic and sodic phases.

No constraints: All other soils.

MICELLANEOUS LAND UNITS

Miscellaneous land units are considered as **severe constraints**. They include: dunes, shifting sands, salt flats, rock debris, desert detritus, and glaciers/snow caps.

APPENDIX IV

TEMPERATURE REGIME REQUIREMENTS OF CROP/LUTs

Notes:

Climates: B = Boreal; Te = Temperate; STR = Sub-tropics; WR = Winter Rainfall; SR = Summer Rainfall; Tr = Tropics

Growth cycle: L/Gc = Total; La = Pre-dormancy; Lb = Post-dormancy

Temperature profile interval symbols:

Temperature intervals (°C)	<-5	-5-0	0-5	5-10	10-15	15-20	20-25	25-30	>30
Totals	L9	L8	L7	L6	L5	L4	L3	L2	L1
Increasing temperatures (winter to summer)	L9a	L8a	L7a	L6a	L5a	L4a	L3a	L2a	L1a
Decreasing temperatures (summer to winter)	L9b	L8b	L7b	L6b	L5b	L4b	L3b	L2b	L1b

Heat Units: TSgc = Temperature Sum during growth cycle

Temperature Growing Period: LGP_{t=5} = Number of days with mean daily temperatures above 5°C

TEMPERATURE REGIME REQUIREMENTS OF CROP/LUTs

Crop	Sub-optimal Conditions	Optimal Conditions
Winter Wheat (Wheat I)	<i>Climates: B, Te, STr (WR+SR)</i> $L6a < 0.667 * Lb$	<i>Climates: B, Te, STr (WR+SR)</i> $L6a < 0.500 * Lb$
Winter Barley (Barley I)	$L6a + L5a > 0.167 * Lb$ $L2a + L2b < 0.333 * Lb$	$L6a + L5a > 0.084 * Lb$ $L2a + L2b < 0.333 * Lb$
Winter Rye (Rye I)	$L1a + L1b = 0$ $L2b + L3b + L4b + L5b < 0.500 * Lb$ $L = 30 + 90$ $L = 35 + 105$ $L = 40 + 120$ $L = 45 + 135$	$L1a + L1b = 0$ $L2b + L3b + L4b + L5b < 0.500 * Lb$ $L3b + L4b + NLb + L6b > La$ $TSgc > 1200 *$ <i>no permafrost</i> $LGP_{t=5} < 365$ <i>dormancy required</i>
Spring Wheat (Wheat II)	<i>Climates: B, Te, STr (WR+SR)</i> $L6a < 0.333 * L$ $L = 105/120/135/150$	<i>Climates: B, Te, STr (WR+SR)</i> $L6a < 0.333 * L$ $L6a + L5a > 0.167 * Lb$ $L2a + L2b < 0.333 * Lb$ $L1a + L1b = 0$ $L2b + L3b + L4b + L5b < 0.500 * Lb$ $TSgc > 1400$ <i>no permafrost</i> $LGP_{t=5} < 365$
Spring Barley (Barley II)	<i>Climates: B, Te, STr (WR+SR)</i> $L6a < 0.333 * L$	<i>Climates: B, Te, STr (WR+SR)</i> $L6a < 0.333 * L$
Spring Rye (Rye II)	$L6a + L5a > 0.167 * Lb$ $L2a + L2b < 0.333 * Lb$ $L1a + L1b = 0$ $L2b + L3b + L4b + L5b < 0.500 * Lb$ $TSgc > 1400$ <i>no permafrost</i> $LGP_{t=5} < 365$	$L6a + L5a > 0.167 * Lb$ $L2a + L2b < 0.333 * Lb$ $L1a + L1b = 0$ $L2b + L3b + L4b + L5b < 0.500 * Lb$ $TSgc > 1700$ <i>no permafrost</i> $LGP_{t=5} < 365$
Wheat (sub-tropics) (Wheat III)	<i>Climates: STr (WR + SR)</i> $L6a < 0.333 * L$ $L = 105$ $L = 120$ $L = 135$ $L = 150$	<i>Climates: STr (WR + SR)</i> $L6a < 0.167 * L$ $L6 + L5 + L4 > 0.333 * Lb$ $L2a + L2b < 0.500 * Lb$ $L1a + L1b = 0$ $TSgc > 1500$ $LGP_{t=5} = 365$
Barley (sub-tropics) (Barley III)	<i>Climates: STr (WR + SR)</i> $L6a < 0.333 * L$ $L = 90$ $L = 105$ $L = 120$ $L = 135$	<i>Climates: STr (WR + SR)</i> $L6a < 0.167 * L$ $L6 + L5 + L4 > 0.333 * Lb$ $L2a + L2b < 0.500 * Lb$ $L1a + L1b = 0$ $TSgc > 1400$ $LGP_{t=5} = 365$
Wheat (tropics) (Wheat IV)	<i>Climates: Tr</i> $L6a < 0.333 * L$ $L = 100$ at 20.0 °C $L = 130$ at 17.5 °C $L = 160$ at 15.0 °C $L = 190$ at 12.5 °C	<i>Climates: Tr</i> $L6a < 0.167 * L$ $L6 + L5 + L4 > 0.333 * Lb$ $L2a + L2b < 0.500 * Lb$ $L1a + L1b = 0$ $TSgc > 1600$ $LGP_{t=5} = 365$
Barley (tropics) (Barley IV)	<i>Climates: Tr</i> $L6a < 0.333 * L$ $L = 100$ at 20.0 °C $L = 130$ at 17.5 °C $L = 160$ at 15.0 °C $L = 190$ at 12.5 °C	<i>Climates: Tr</i> $L6a < 0.167 * L$ $L6 + L5 + L4 > 0.333 * Lb$ $L2a + L2b < 0.500 * Lb$ $L1a + L1b = 0$ $TSgc > 1500$ $LGP_{t=5} = 365$

* applicable to post-dormancy period only

Crop	Sub-optimal Conditions	Optimal Conditions
Indica Rice (wetland) <i>L = 105/120/135/150</i>	<i>Climates: Tr, STR (SR+WR)</i> <i>L5=L6=0</i> <i>L3 + L2+ L1 >0.833*L</i> <i>L4a < 0.167*L</i> <i>L4b < 0.167*L</i> <i>TSgc>2400</i>	<i>Climates: Tr, STR (SR+WR)</i> <i>L6=L5=L4 = 0</i> <i>L3+L2+L1 = 1.000*L</i> <i>L1 < 0.667*L</i> <i>TSgc >3000</i>
Indica Rice (dryland) <i>L = 105/120/135</i>	<i>Climates: Tr</i> <i>L5=L6=0</i> <i>L3 + L2+ L1 >0.833*L</i> <i>L4a < 0.167*L</i> <i>L4b < 0.167*L</i> <i>TSgc>2400</i>	<i>Climates: Tr</i> <i>L6=L5=L4 = 0</i> <i>L3+L2+L1 = 1.000*L</i> <i>L1 < 0.667*L (not implemented)r</i> <i>TSgc >3000</i>
Japonica Rice (wetland) <i>L = 105/120/135/150</i>	<i>Climates: Tr, STR (SR+WR), Te</i> <i>L5a+L4a < 0.400*L</i> <i>L4 >0</i> <i>L2a+L2b < 0.667*L</i> <i>L1a+L1b < 0.200*L</i> <i>L4b+L5b < 0.250*L</i> <i>L6=0</i> <i>TSgc > 1800</i>	<i>Climates: Tr, STR (SR+WR), Te</i> <i>L5a+L4a < 0.400*L</i> <i>L2a+L2b < 0.667*L</i> <i>L1a+L1b < 0.200*L</i> <i>L4b+L5b < 0.250*L</i> <i>L6=0</i> <i>TSgc > 2200</i>
Lowland Maize and Sorghum (Maize I) (Sorghum I) <i>L = 90/105/120/135</i>	<i>Climates: Tr</i> <i>L4a+L4b < 0.167*L</i> <i>TSgc > 2200</i>	<i>Climates: Tr</i> <i>L4 = 0</i> <i>TSgc > 2500</i>
Highland Maize and Sorghum (Maize II) (Sorghum II) <i>L = 105 at 20.0 °C</i> <i>L = 180 at 17.5 °C</i> <i>L = 300 at 15.0 °C</i>	<i>Climates: Tr</i> <i>L1 = 0</i> <i>L2 = 0</i> <i>L5 < 0.500*L</i> <i>L6=0</i> <i>L3a+L3b < 0.333L</i> <i>TSgc > 2200</i>	<i>Climates: Tr</i> <i>L1 = 0</i> <i>L2 = 0</i> <i>L5 < 0.333*L</i> <i>L6=0</i> <i>L3a+L3b < 0.333*L</i> <i>TSgc > 2500</i>
Maize (sub-tropics, grain) (Maize III) <i>L = 105/120/135/150/165/180</i>	<i>Climates: STR (SR+WR), Te</i> <i>L5a+L5b < 0.200*L</i> <i>L6=0</i> <i>TSgc>1900</i>	<i>Climates: STR (SR+WR), Te</i> <i>L5 = <0.200*L</i> <i>L6=0</i> <i>TSgc>2400</i>
Maize (temperate, silage) (Maize IV) <i>L = 105/120/135/150/165/180</i>	<i>Climates: STR (SR+WR), Te</i> <i>L5 < 0.667*L</i> <i>L6=0</i> <i>TSgc>1700</i> <i>no permafrost</i>	<i>Climates: STR (SR+WR), Te</i> <i>L5 < 0.667*L</i> <i>L6=0</i> <i>TSgc > 1900</i> <i>no permafrost</i>
Irish Potato <i>L = 90/120/150/180</i>	<i>Climates: B, Te, STR, Tr</i> <i>L6a < 0.333*L</i> <i>L6b < 0.167*L</i> <i>L2 < 0.333*L</i> <i>L1 = 0</i> <i>L6+L5+L4 > 0.400*L</i> <i>TSgc >1200</i> <i>no permafrost</i>	<i>Climates: B, Te, STR, Tr</i> <i>L6a < 0.333*L</i> <i>L6b < 0.167*L</i> <i>L2 < 0.333*L</i> <i>L1 = 0</i> <i>L6+L5+L4 > 0.400*L</i> <i>TSgc>1500</i> <i>no permafrost</i>
Pearl Millet <i>L = 70/90</i>	<i>Climates: Tr</i> <i>L4a+L4b < 0.167*L</i> <i>L5=L6=0</i> <i>TSgc > 1600</i>	<i>Climates: Tr</i> <i>L4 = 0</i> <i>L5=L6=0</i> <i>TSgc > 1800</i>
Cowpea <i>L = 80/100/120</i>	<i>Climates: Tr</i> <i>L4a+L4b < 0.167*L</i> <i>L5=L6=0</i> <i>TSgc > 1800</i>	<i>Climates: Tr</i> <i>L4 = 0</i> <i>L5=L6=0</i> <i>TSgc > 2100</i>
Cassava <i>L = 12 months</i>	<i>Climates: Tr</i> <i>L4 < 0.333*L</i> <i>L1 < 0.667 * L</i> <i>L5=L6=0</i> <i>TSgc > 6500</i>	<i>Climates: Tr</i> <i>L4 < 0.167*L</i> <i>L1 < 0.667 * L</i> <i>L5=L6=0</i> <i>TSgc > 7500</i>

Crop	Sub-optimal Conditions	Optimal Conditions
Sweet Potato <i>L = 150/180/210</i>	<i>Climates: Tr, STr (SR)</i> $L4 < 0.333 * L$ $L5 = L6 = 0$ $L1 < 0.500 * L$ $TSgc > 3500$	<i>Climates: Tr, STr (SR)</i> $L4 < 0.333 * L$ $L5 = L6 = 0$ $L1 < 0.500 * L$ $TSgc > 4000$
Foxtail Millet (Setaria) <i>L = 75/90/105/120</i>	<i>Climates: STr (SR+WR), Te</i> $L5a + L5b < 0.167 * L$ $L3 > 0$ $L6 = 0$ $TSgc > 1500$	<i>Climates: STr (SR+WR), Te</i> $L5 = 0$ $L3 > 0$ $L6 = 0$ $TSgc > 1800$
Sugarcane <i>L = 12 months</i>	<i>Climates: Tr, STr (SR + WR)</i> $L4 + L5 < 0.667 * L$ $L5 + L4 + L3 > 0.084 * L$ (n.a.) $L6 = 0$ $TSgc > 6250$	<i>Climates: Tr, STr (SR + WR)</i> $L4 < 0.667 * L$ $L4 + L3 > 0.084 * L$ $L5 + L6 = 0$ $TSgc > 6500$
Sugarbeet <i>L = 150/165/180/195/210</i>	<i>Climates: Te, STr (SR+WR)</i> $L6a < 0.333 * L; L6b < 0.167 * L$ $L6 + L5 > 0.167 * L$ $L2 < 0.400 * L$ $L1 = 0$ $TSgc > 1600$ <i>no permafrost</i>	<i>Climates: Te, STr (SR+WR)</i> $L6a < 0.333 * L; L6b < 0.167 * L$ $L6 + L5 > 0.167 * L$ $L2 < 0.400 * L$ $L1 = 0$ $TSgc > 2000$ <i>no permafrost</i>
Lowland Phaseolus Bean <i>L = 90/120/150</i>	<i>Climates: Tr</i> $L4a + L4b < 0.167 * L$ $L6 + L5 = 0$ $TSgc > 1800$	<i>Climates: Tr</i> $L4 = 0$ $L6 + L5 = 0$ $TSgc > 2400$
Highland Phaseolus Bean <i>L = 120 at 17.5 °C</i> <i>L = 150 at 15.0 °C</i> <i>L = 180 at 12.5 °C</i>	<i>Climates: Tr</i> $L5a + L5b < 0.500 * L$ $L3a + L3b < 0.050 * L$ $L1 + L2 = 0$ $L6 = 0$ $TSgc > 1500$	<i>Climates: Tr</i> $L5a + L5b < 0.500 * L$ $L3a + L3b < 0.050 * L$ $L1 + L2 = 0$ $L6 = 0$ $TSgc > 1800$
Phaseolus Bean (temperate) <i>L = 90/120/150</i>	<i>Climates: Te, STr (SR+WR)</i> $L5 < 0.667 * L$ $L5 + L4 + L3 > 0.500 * L$ $L1 = 0$ $L6 = 0$ $TSgc > 1400$	<i>Climates: Te, STr (SR+WR)</i> $L5 < 0.667 * L$ $L5 + L4 + L3 > 0.500 * L$ $L1 = 0$ $L6 = 0$ $TSgc > 1700$
Chickpea (cold tolerant) <i>L = 150/180</i> <i>Winter sowing (cold resistant)</i> <i>(data from ICARDA)</i>	<i>Climates: STr (WR)</i> $L6a < 0.333 * L$ $L5b + L6b < 0.167 * L$ $L6a + L5a + L4a > 0.333 * L$ $L4b + L3b + L2b = 0$ $L1 < 0.167 * L$ $L3a > 0$ $TSgc > 1700$	<i>Climates: STr (WR)</i> $L6a < 0.333 * L$ $L5b + L6b < 0.167 * L$ $L6a + L5a + L4a > 0.333 * L$ $L4b + L3b + L2b = 0$ $L1 < 0.167 * L$ $L3a > 0$ $TSgc > 2200$
Chickpea <i>L = 90/105/120</i>	<i>Climates: Tr, STr (SR+WR)</i> $L6a < 0.167 * L$ $L1 < 0.167 * L$ $L6b + L5b + L4b + L3b + L2b = 0$ $L6a + L5a + L4a > 0.167 * L$ $L3a > 0$ $TSgc > 1500$	<i>Climates: Tr, STr (SR+WR)</i> $L6 = 0.167$ $L1 < 0.167 * L$ $L5b + L4b + L3b + L2b = 0$ $L6a + L5a + L4a > 0.167 * L$ $L3a > 0$ $TSgc > 2100$
Groundnut <i>L = 90/105/120</i>	<i>Climates: Tr, STr (SR+WR), Te</i> $L4a + L4b < 0.167 * L$ $L5 = L6 = 0$ $TSgc > 2200$	<i>Climates: Tr, STr (SR+WR), Te</i> $L4 = 0$ $L5 = L6 = 0$ $TSgc > 2500$
Soybean (tropics) <i>L = 90/105/120</i>	<i>Climates: Tr</i> $L4a + L4b < 0.500 * L$ $L5 = L6 = 0$ $TSgc > 2100$	<i>Climates: Tr</i> $L4 < 0.333 * L$ $L5 = L6 = 0$ $TSgc > 2400$

Crop	Sub-optimal Conditions	Optimal Conditions
Soybean (sub-tropics) <i>L = 105/120/135</i>	<i>Climates:STr(SR+WR), Te</i> $L5 = 0$ $L3+L4 > 0.333*L$ $L1 < 0.333*L$ $TSgc > 1700$	<i>Climates:STr(SR+WR), Te</i> $L5 = 0$ $L6 = 0$ $L3+L4 > 0.333*L$ $L1 < 0.333*L$ $TSgc > 2000$
Sunflower (tropics) <i>L = 135/150/165</i>	<i>Climates:Tr</i> $L5 + L4 + L3 > 0.500*L$ $L3 < 0.500*L$ $L4 > 0.167 * L$ $L1 = L2 = L6 = 0$ $TSgc > 2200$	<i>Climates:Tr</i> $L5 + L4 + L3 > 0.500* L$ $L3 < 0.500*L$ $L4 > 0.167 * L$ $L1 = L2 = L6 = 0$ $TSgc > 2500$
Sunflower (sub-tropics) <i>L = 135/150/165</i>	<i>Climates:STr (SR+WR), Te</i> $L5 < 0.300*L$ $L5+L4 + L3 > 0.400*L$ (n.a.) $L1 < 0.333*L$ $L6 = 0$ $TSgc > 2000$	<i>Climates:STr (SR+WR), Te</i> $L5 < 0.200*L$ $L5+L4+L3 > 0.400*L$ (n.a.) $L1 < 0.333*L$ $L6 = 0$ $TSgc > 2400$
Winter Rape <i>L = 35 + 105</i> <i>L = 45 + 120</i>	<i>Climates: Te, STr (SR+TR)</i> $L6a < 0.667*Lb$ $L2a+L2b < 0.400*Lb$ $L1a+L1b = 0$ $L2b+L3b+L4b+L5b < 0.500*Lb$ $N4b+N5b +N6b > La$ $TSgc > 1200 *$ $LGP_{t=5} < 365$ <i>dormancy required</i> <i>no permafrost</i>	<i>Climates: Te, STr (SR+TR)</i> $L6a < 0.500*Lb$ $L2a+L2b < 0.400*Lb$ $L1a+L1b = 0$ $L2b+L3b+L4b+L5b < 0.500*Lb$ $N4b+N5b +N6b > La$ $TSgc > 1400 *$ $LGP_{t=5} < 365$ <i>dormancy required</i> <i>no permafrost</i>
Spring Rape <i>L = 135/150/165</i>	<i>Climates: Te, STr (SR+WR)</i> $L6a < 0.333*L$ $L2a+L2b < 0.400*L$ $L1a+L1b = 0$ $L2b+L3b+L4b+L5b < 0.500*L$ $TSgc > 1400$ $LGP_{t=5} < 365$ <i>no permafrost</i>	<i>Climates: Te, STr (SR+WR)</i> $L6a < 0.333*L$ $L2a+L2b < 0.400*L$ $L1a+L1b = 0$ $L2b+L3b+L4b+L5b < 0.500*L$ $TSgc > 1800$ $LGP_{t=5} < 365$ <i>no permafrost</i>
Rape (rabi) <i>L = 135/150/165</i>	<i>Climates: Tr, STr (SR + WR)</i> $L6a < 0.333*L$ $L2a+L2b < 0.500*L$ $L1a+L1b = 0$ $L6+L5+L4 > 0.167*L$ $TSgc > 1400$ $LGP_{t=5} = 365$	<i>Climates: Tr, STr (SR + WR)</i> $L6a < 0.333*L$ $L2a+L2b < 0.500*L$ $L1a+L1b = 0$ $L6+L5+L4 > 0.167*L$ $TSgc > 1800$ $LGP_{t=5} = 365$
Cotton (tropics) <i>L = 135/150/165/180</i>	<i>Climates: Tr</i> $L4a+L4b < 0.250*L$ $TSgc > 3000$	<i>Climates: Tr</i> $L4 = 0$ $TSgc > 3400$
Cotton (sub-tropics) <i>L = 135/150/165</i>	<i>Climates:STr (SR+WR), Te</i> $L4a+L4b < 0.333*L$ $TSgc > 2700$	<i>Climates:STr (SR+WR), Te</i> $L4a+L4b < 0.167*L$ $TSgc > 3000$
Banana/Plantain <i>L = 12 months</i>	<i>Climate: Tr, STr (SR+WR)</i> $L5 < 0.667*L$ $L2+L3 > 0.333*L$ $L1 < 0.667 * L$ $TSgc > 6000$	<i>Climate: Tr, STr (SR+WR)</i> $L5 < 0.500*L$ $L2+L3 > 0.400*L$ $L1 < 0.500 * L$ $TSgc > 7000$
Oil Palm <i>L = 12 months</i>	<i>Climate: Tr, STr (SR)</i> $L4a+L4b < 0.333*L$ $TSgc > 7500$	<i>Climate: Tr, STr (SR)</i> $L4 < 0.167*L$ $TSgc > 8000$

* applicable to post-dormancy period only

Crop	Sub-optimal Conditions	Optimal Conditions
Olive	<i>Climates: STR (SR+WR), Te</i>	<i>Climates: STR (SR+WR), Te</i>
<i>L = 12 months</i>	$L8 = L9 = 0$	$L8 = L9 = 0$
	$L7 + L6 + L5 + L4 > 0.400*L$	$L7 + L6 + L5 + L4 > 0.400*L$
	$L4 + L3 + L2 + L1 > 0.333*L$	$L4 + L3 + L2 + L1 > 0.333*L$
	$TSgc > 4000$	$TSgc > 5000$
Alfalfa (Lucerne)	<i>Climates: Te, STR (SR+WR)</i>	<i>Climates: Te, STR (SR+WR)</i>
<i>L = LGP_{t=5}</i>	$Gc(L) = (LGP_{t=5}) > 120 \text{ days}$	$Gc(L) = (LGP_{t=5}) > 150 \text{ days}$
	$L6 < 0.500*L$	$L6 < 0.500*L$
	$L1 < 0.333*L$	$L1 < 0.333*L$
	$TSgc > 1800$	$TSgc > 2250$
Grasses	<i>Climates: Tr, STR (SR+WR), Te</i>	<i>Climates: Tr, STR (SR+WR), Te</i>
<i>L = LGP_{t=5}</i>	$TSgc > 750$	$TSgc > 1000$
	$Gc(L) = (LGP_{t=5}) > 90 \text{ days}$	$Gc(L) = (LGP_{t=5}) > 120 \text{ days}$
Grasses	<i>Climates: Te, B</i>	<i>Climates: Te</i>
<i>L = LGP_{t=5}</i>	$TSgc > 750$	$TSgc > 1000$
	$Gc(L) = (LGP_{t=5}) > 90 \text{ days}$	$Gc(L) = (LGP_{t=5}) > 120 \text{ days}$

APPENDIX V

CALCULATION OF REFERENCE EVAPOTRANSPIRATION ACCORDING TO PENMAN-MONTEITH COMBINATION EQUATION

The calculation of reference evapotranspiration (ET_o), i.e., the rate of evapotranspiration from a hypothetical reference crop with an assumed crop height of 12 cm, a fixed canopy resistance of 70ms^{-1} and an albedo of 0.23 (closely resembling the evapotranspiration from an extensive surface of green grass), is done according to the Penman-Monteith equation (Monteith, 1965, 1981; FAO, 1992b). The calculation procedure uses a standardized set of input parameters, as follows:

T_{\max}	...	maximum daily temperature ($^{\circ}\text{C}$)
T_{\min}	...	minimum daily temperature ($^{\circ}\text{C}$)
RH	...	mean daily relative humidity (%)
$U2$...	wind speed measurement (ms^{-1})
SD	...	bright sunshine hours per day (hours)
A	...	elevation (m)
L	...	latitude (deg)
J	...	Julian date, i.e., number of day in year

The *Penman-Monteith combination equation* can be written in terms of an aerodynamic and a radiation term (FAO, 1992b):

$$ET_o = ET_{ar} + ET_{ra} \quad (1)$$

where the *aerodynamic term* can be approximated by

$$ET_{ar} = \frac{\gamma}{\vartheta + \gamma^*} \cdot \frac{900}{T_a + 273} \cdot U2 \cdot (e_a - e_d) \quad (2)$$

and the *radiation term* by

$$ET_{ra} = \frac{\vartheta}{\vartheta + \gamma^*} \cdot (R_n - G) \cdot \frac{1}{\lambda} \quad (3)$$

where variables in (2) and (3) are as follows:

γ	...	psychrometric constant ($\text{kPa } ^{\circ}\text{C}^{-1}$)
γ^*	..	modified psychrometric constant ($\text{kPa } ^{\circ}\text{C}^{-1}$)
ϑ	...	slope of vapor pressure curve ($\text{kPa } ^{\circ}\text{C}^{-1}$)
T_a	...	average daily temperature ($^{\circ}\text{C}$)
e_a	...	saturation vapor pressure (kPa)
e_d	...	vapor pressure at dew point (kPa)
$(e_a - e_d)$...	vapor pressure deficit (kPa)
$U2$...	wind speed measurement (ms^{-1})
R_n	...	net radiation flux at surface ($\text{MJ m}^{-2} \text{d}^{-1}$)
G	...	soil heat flux ($\text{MJ m}^{-2} \text{d}^{-1}$)
λ	...	latent heat of vaporization (MJ kg^{-1})

In the calculation procedure for the reference crop we use the following relationships to define terms in (2):

Average daily temperature:

$$T_a = 0.5(T_{\max} + T_{\min}) \quad (4)$$

Latent heat of vaporization:

$$\lambda = 2.501 - 0.002361 T_a \quad (5)$$

Atmospheric pressure (kPa) at elevation A:

$$P = 101.3 \left(\frac{293 - 0.0065 A}{293} \right)^{5.256} \quad (6)$$

Psychrometric constant:

$$\gamma = 0.0016286 \cdot \frac{P}{\lambda} \quad (7)$$

Aerodynamic resistance:

$$r_a = \frac{208}{U^2} \quad (8)$$

Crop canopy resistance:

$$r_c = \frac{R_l}{0.5 LAI} \quad (9)$$

where under ambient CO₂ concentrations the average daily stomata resistance of a single leaf, R_l (sm⁻¹), is set to $R_l = 100$, and leaf area index of the reference crop is assumed as $LAI = 24 \cdot 0.12 = 2.88$.

Modified psychrometric constant:

$$\gamma^* = \gamma \left(1 + \frac{r_c}{r_a} \right) \quad (10)$$

Saturation vapor pressure e_a for given temperatures T_{\min} and T_{\max}

$$e_{ax} = 0.6108 \exp \left(\frac{17.27 T_{\max}}{237.3 + T_{\max}} \right) \quad (11)$$

$$e_{an} = 0.6108 \exp \left(\frac{17.27 T_{\min}}{237.3 + T_{\min}} \right) \quad (12)$$

$$e_a = 0.5 (e_{ax} + e_{an}) \quad (13)$$

Vapor pressure at dew point, e_d :

$$e_d = \frac{RH}{100} \cdot \frac{0.5}{\left(\frac{1}{e_{ax}} + \frac{1}{e_{an}} \right)} \quad (14)$$

Slope of vapor pressure curve, ϑ , for given temperatures T_{\max} and T_{\min} :

$$\vartheta_x = \frac{4096 e_{ax}}{(237.3 + T_{\max})^2} \quad (15)$$

$$\vartheta_n = \frac{4096 e_{an}}{(237.3 + T_{\min})^2} \quad (16)$$

$$\vartheta = (\vartheta_x + \vartheta_n) \quad (17)$$

Using (4)-(17) all variables in (2) can be calculated from the input parameters of the ET_o computer subroutine. To determine the remaining variables R_n and G used in the radiation term ET_{ra} of equation (3), we proceed with the following calculation steps:

Latitude expressed in rad:

$$\varphi = \frac{L\pi}{180} \quad (18)$$

Solar declination (rad):

$$\delta = 0.4093 \cdot \sin\left(\frac{2\pi}{365} J - 1.405\right) \quad (19)$$

Relative distance Earth to Sun:

$$d = 1 + 0.033 \cos\left(\frac{2\pi}{365} J\right) \quad (20)$$

Sunset hour angle (rad):

$$\psi = \arccos(-\tan \varphi \tan \delta) \quad (21)$$

Extraterrestrial radiation ($\text{MJ m}^{-2} \text{d}^{-1}$):

$$R_a = 37.586 d (\psi \sin \varphi \sin \delta + \cos \varphi \cos \delta \sin \psi) \quad (22)$$

Maximum daylight hours:

$$DL = \frac{24}{\pi} \psi \quad (23)$$

Short-wave radiation R_s ($\text{MJ m}^{-2} \text{d}^{-1}$)

$$R_s = \left(0.25 + 0.5 \frac{SD}{DL}\right) R_a \quad (24)$$

For a reference crop with an assumed albedo coefficient $\alpha = 0.23$ net incoming short-wave radiation R_{ns} ($\text{MJ m}^{-2} \text{d}^{-1}$) is:

$$R_{ns} = 0.77 R_s \quad (25)$$

Net outgoing long-wave radiation R_{nl} ($\text{MJ m}^{-2} \text{d}^{-1}$) is estimated using:

$$R_{nl} = 4.903 \cdot 10^{-9} \left(0.1 + 0.9 \frac{SD}{DL}\right) (0.34 - 0.139 \sqrt{e_d}) \frac{(273.16 + T_{\max})^4 + (273.16 + T_{\min})^4}{2} \quad (26)$$

Using (25) and (26), net radiation flux at surface, R_n , becomes

$$R_n = R_{ns} - R_{nl} \quad (27)$$

Finally, *soil heat flux* is approximated using

$$G = 0.14 (T_{a,n} - T_{a,n-1}) \quad (28)$$

where $T_{a,n}$ and $T_{a,n-1}$ are average monthly temperatures of current and previous month, respectively. With equations (5), (10), (17), (27) and (28) all variables in (3) are defined and can be calculated from the input parameters described at the beginning of this Appendix.

APPENDIX VI

BIOMASS AND YIELD CALCULATION

The AEZ methodology for the calculation of potential net biomass and yields is derived from Kassam (1977). This model, based on eco-physiological principles, is outlined below:

To calculate the net biomass production (B_n) of a crop, an estimation of the gross biomass production (B_g) and respiration loss (R) is required:

$$B_n = B_g - R \quad (1)$$

The equation relating the rate of net biomass production (b_n) to the rate of gross biomass production (b_g) and the respiration rate (r) is:

$$b_n = b_g - r \quad (2)$$

The maximum rate of net biomass production (b_{nm}) is reached when the crop fully covers the ground surface. The period of maximum net crop growth, i.e., the point in time when maximum net biomass increments occur, is indicated by the inflection point of the cumulative growth curve. When the first derivative of net biomass growth is plotted against time the resulting graph resembles a normal distribution curve. The model assumes that the average rate of net production (b_{na}) over the entire growth cycle is half the maximum growth rate, i.e., $b_{na} = 0.5 b_{nm}$. The net biomass production for a crop of N days (B_n) is then:

$$B_n = 0.5 b_{nm} \times N \quad (3)$$

The maximum rate of gross biomass production (b_{gm}) is related to the maximum net rate of CO₂ exchange of leaves (P_m) which is dependent on temperature, the photosynthesis pathway of the crop, and the level of atmospheric CO₂ concentration.

For a standard crop, i.e., a crop in adaptability group I with $P_m = 20 \text{ kg ha}^{-1} \text{ hr}^{-1}$ and a leaf area index of LAI = 5, the rate of gross biomass production b_{gm} is calculated from the equation:

$$b_{gm} = F \times b_o + (1 - F) b_c \quad (4)$$

where:

F = the fraction of the daytime the sky is clouded, $F = (A_c - 0.5 R_g) / (0.8 A_c)$, where A_c (or PAR) is the maximum active incoming short-wave radiation on clear days (de Wit, 1965), and R_g is incoming short-wave radiation (both are measured in $\text{cal cm}^{-2} \text{ day}^{-1}$)

b_o = gross dry mater production rate of a standard crop for a given location and time of the year on a completely overcast day, ($\text{kg ha}^{-1} \text{ day}^{-1}$) (de Wit, 1965)

b_c = gross dry mater production rate of a standard crop for a given location and time of the year on a perfectly clear day, ($\text{kg ha}^{-1} \text{ day}^{-1}$) (de Wit, 1965)

When P_m is greater than $20 \text{ kg ha}^{-1} \text{ hr}^{-1}$, b_{gm} is given by the equation:

$$b_{gm} = F (0.8 + 0.01P_m) b_o + (1 - F) (0.5 + 0.025 P_m) b_c \quad (5)$$

When P_m is less than $20 \text{ kg ha}^{-1} \text{ hr}^{-1}$, b_{gm} is calculated according to:

$$b_{gm} = F (0.5 + 0.025 P_m) b_o + (1 - F) (0.05 P_m) b_c \quad (6)$$

To calculate the maximum rate of net biomass production (b_{nm}), the maximum rate of gross biomass production (b_{gm}) and the rate of respiration (r_m) are required. Here, growth respiration is considered a linear function of the rate of gross biomass production (McCree, 1974), and maintenance respiration a linear function of net biomass that has already been accumulated (B_m) When the rate of gross biomass production is b_{gm} , the respiration rate r_m is:

$$r_m = k b_{gm} + c B_m \quad (7)$$

where k and c are the proportionality constants for growth respiration and maintenance respiration respectively, and B_m is the net biomass accumulated at the time of maximum rate of net biomass production. For both legume and non legume crops k equals 0.28. However, c is temperature dependent and differs for the two crop groups. At $30 \text{ }^\circ\text{C}$, factor c_{30} for a legume crop equals 0.0283 and for a non-legume crop 0.0108. The temperature dependence of c_t for both crop groups is modelled with a quadratic function:

$$c_t = c_{30} (0.0044 + 0.0019 T + 0.0010 T^2). \quad (8)$$

It is assumed that the cumulative net biomass B_m of the crop (i.e., biomass at the inflection point of the cumulative growth curve) equals half the net biomass that would be accumulated at the end of the crop's growth cycle. Therefore, we set $B_m = 0.5 B_n$, and using (3), B_m for a crop of N days is determined according to:

$$B_m = 0.25 b_{nm} \times N \quad (9)$$

By combining the respiration equation with the equation for the rate of gross photosynthesis, the maximum rate of net biomass production (b_{nm}) or the rate of net dry matter production at full cover for a crop of N days becomes:

$$b_{nm} = 0.72 b_{gm} / (1 + 0.25 c_t N) \quad (10)$$

Finally, the net biomass production (B_n) for a crop of N days, where $0.5 b_{nm}$ is the seasonal average rate of net biomass production, can be derived as:

$$B_n = (0.36 b_{gm} \times L) / (1/N + 0.25 c_t) \quad (11)$$

where:

b_{gm} = maximum rate of gross biomass production at leaf area index (LAI) of 5

L = growth ratio, equal to the ratio of b_{gm} at actual LAI to b_{gm} at LAI of 5

N = length of normal growth cycle

$c_t =$ maintenance respiration, dependent on both crop and temperature according to equation (8)

Potential yield (Y_p) is estimated from net biomass (B_n) using the equation:

$$Y_p = H_i \times B_n \quad (12)$$

where:

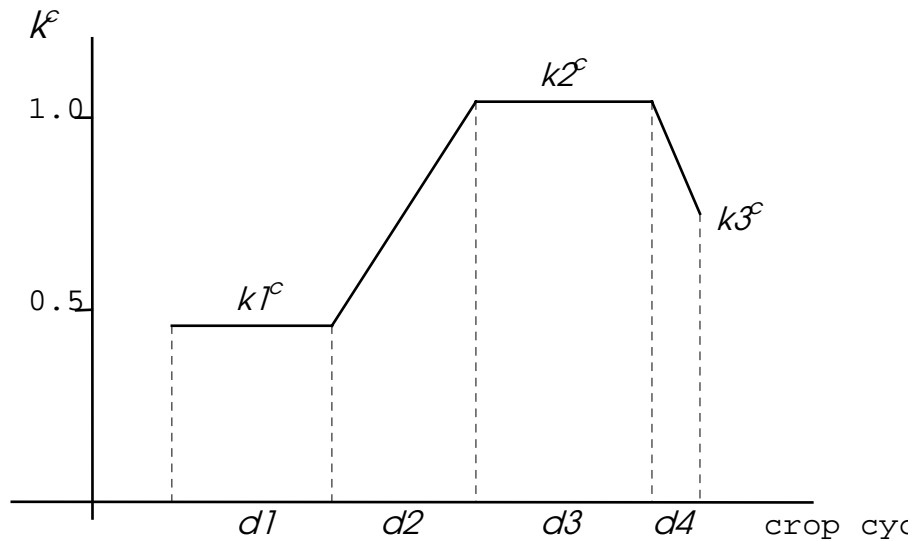
$H_i =$ harvest index, i.e., proportion of the net biomass of a crop that is economically useful

Thus, climate and crop characteristics that apply in the computation of net biomass and yield are: (a) heat and radiation regime over the crop cycle, (b) crop adaptability group to determine applicable rate of photosynthesis P_m , (c) length of growth cycle (from emergence to physiological maturity), (d) length of yield formation period, (e) leaf area index at maximum growth rate, and (f) harvest index.

The calculation of moisture limited yields follows the procedures described in FAO (1992a), known as the CROPWAT method. In this approach, the crop-specific potential evapotranspiration ETo^c is related to reference evapotranspiration ETo as,

$$ETo^c = k^c \times ETo \quad (13)$$

where k^c is calculated from a piecewise linear function as sketched below:



The function is parameterized by means of seven parameters. Four coefficients, d_1, \dots, d_4 , relate to the characteristics of the crop cycle, denoting the length (in days) of four crop development stages, namely, initial stage, vegetative stage, reproductive stage, and maturation stage. Another three parameters, k_1^c, k_2^c and k_3^c , define relationship (13) respectively for the initial stage, the reproductive phase, and the end of the maturation stage.

Let D_1, \dots, D_4 denote the days belonging to each of the four crop growth stages,

$$D_1 = \{j \mid 1 \leq j \leq d_1\},$$

$$D_2 = \{j \mid d_1 < j \leq d_1 + d_2\},$$

$$D_3 = \{j \mid d1 + d2 < j \leq d1 + d2 + d3\}, \text{ and}$$

$$D_4 = \{j \mid d1 + d2 + d3 < j \leq d1 + d2 + d3 + d4\},$$

then the value of k^c for a particular day j is defined by:

$$k_j^c = \begin{cases} k1^c & j \in D_1 \\ k1^c + (j - d1) \cdot \frac{k2^c - k1^c}{d2} & j \in D_2 \\ k2^c & j \in D_3 \\ k2^c + (j - (d1 + d2 + d3)) \cdot \frac{k3^c - k2^c}{d4} & j \in D_4 \end{cases} \quad (14)$$

Using (13) and (14), crop-specific potential evapotranspiration over the four crop growth stages, $TETo_k^c$, and the entire crop cycle, $TETo^c$, can be calculated:

$$TETo_k^c = \sum_{j \in D_k} k_j^c \cdot ETo_j \quad k = 1, \dots, 4 \quad (15)$$

$$d0 = d1 + d2 + d3 + d4$$

$$TETo^c = \sum_{j=1}^{d0} k_j^c \cdot ETo_j \quad (16)$$

Similarly, applying a crop-specific soil water balance, actual evapotranspiration is calculated:

$$TETA_k^c = \sum_{j \in D_k} ETA_j^c \quad k = 1, \dots, 4 \quad (17)$$

$$TETA^c = \sum_{j=1}^{d0} ETA_j^c \quad (18)$$

where ETA^c is determined according to (see also Chapter 3.4):

$$W_{j+1}^c = \min(W_j^c + P_j - ETA_j^c, Sa) \quad (19)$$

$$ETA_j^c = \begin{cases} ETo_j^c & \text{if } (W_j^c + P_j) \cdot d \geq Sa \cdot d \cdot (1 - p_j^c) \\ \rho_j \cdot ETo_j^c & \text{else} \end{cases} \quad (20)$$

with,

$$\rho_j = \frac{ETA_j^c}{ETo_j^c} = \frac{W_j^c + P_j}{Sa \cdot (1 - p_j^c)} \quad (21)$$

- j number of day in year
- Sa available soil moisture holding capacity (mm/m)
- d rooting depth (m)
- p_j^c soil water depletion fraction below which $ETA < ETo$
- ρ_j actual evapotranspiration proportionality factor.

S_a and d are defined by the respective values of the soil units in individual grid-cells. The computation of water-limited yields Y_a is now easily obtained, following FAO (1979 and 1992a):

$$1 - \frac{Y_a}{Y_p} = k^y \cdot \left(1 - \frac{ETa^c}{ETo^c}\right) \quad (22)$$

We evaluate (22) in two variants, first over the entire growth cycle and then according to individual growth stages. The more severe of the two conditions determines Y_a . The respective reduction multipliers f_0 and f_1 are defined by,

$$f_0 = 1 - k_0^y \cdot \left(1 - \frac{TETa^c}{TETo^c}\right) \quad (23)$$

and

$$f_1 = \prod_{k=1}^4 \left(1 - k_k^y \cdot \left(1 - \frac{TETa_k^c}{TETo_k^c}\right)\right) \quad (24)$$

where the coefficient expressing the sensitivity of crop yield to moisture deficit, k^y , are based on FAO (1992a).

Applying (23) and (24) to potential yield from (12), we obtain the final results,

$$Y_a = \min(f_1, f_2) \cdot Y_p \quad (25)$$

The parameters for lengths of crop stages, crop-specific evapotranspiration, and for sensitivity of yield to moisture deficit, used in this study, are listed in Appendix 7.

APPENDIX VII

PARAMETERS FOR BIOMASS AND YIELD CALCULATIONS

PARAMETERS FOR BIOMASS AND YIELD CALCULATIONS

CROPS	Growth cycle (GC)	Adaptability group	High Inputs		Intermediate Inputs		Low Inputs		Dependence of Rate of Leaf Photosynthesis (Pm) on Temperature (°C)								
			HI	Max. LAI	HI	Max. LAI	HI	Max. LAI	5	10	15	20	25	30	35	40	45
Wheat (winter)	30-90 days	C3/I	0.45	4.5	0.35.	3.5	0.25	2.5	5	15	25	25	20	10	0	0	0
Wheat (winter)	35-105 days	C3/I	0.45	5.0	0.35.	3.8	0.25	2.5	5	15	25	25	20	10	0	0	0
Wheat (winter)	40-120 days	C3/I	0.50	5.5	0.40.	4.0	0.30	2.5	5	15	25	25	20	10	0	0	0
Wheat (winter)	45-135 days	C3/I	0.50	5.5	0.40.	4.0	0.30	2.5	5	15	25	25	20	10	0	0	0
Wheat (spring)	105 days	C3/I	0.40	3.5	0.30	2.6	0.20	1.8	5	15	20	20	15	5	0	0	0
Wheat (spring)	120 days	C3/I	0.40	4.0	0.30	3.0	0.20	2.0	5	15	20	20	15	5	0	0	0
Wheat (spring)	135 days	C3/I	0.40	4.5	0.30	3.4	0.20	2.3	5	15	20	20	15	5	0	0	0
Wheat (spring)	150 days	C3/I	0.40	5.0	0.30	3.8	0.20	2.5	5	15	20	20	15	5	0	0	0
Wheat (sub-tropics)	105 days	C3/I	0.45	4.0	0.35	3.0	0.25	2.0	5	15	25	25	20	15	5	0	0
Wheat (sub-tropics)	120 days	C3/I	0.45	4.5	0.35	3.3	0.25	2.0	5	15	25	25	20	15	5	0	0
Wheat (sub-tropics)	135 days	C3/I	0.45	5.0	0.35	3.8	0.25	2.5	5	15	25	25	20	15	5	0	0
Wheat (sub-tropics)	150 days	C3/I	0.45	5.0	0.35	3.8	0.25	2.5	5	15	25	25	20	15	5	0	0
Wheat (tropics)	100 days	C3/I	0.40	3.5	0.30	2.6	0.20	1.8	5	15	25	25	20	15	5	0	0
Wheat (tropics)	130 days	C3/I	0.40	4.5	0.30	3.4	0.20	2.3	5	15	25	25	20	15	5	0	0
Wheat (tropics)	160 days	C3/I	0.40	5.0	0.30	3.8	0.20	2.5	5	15	25	25	20	15	5	0	0
Wheat (tropics)	190 days	C3/I	0.40	5.0	0.30	3.8	0.20	2.5	5	15	25	25	20	15	5	0	0
Japonica Rice (wetland)	105 days	C3/II	0.40	5.0	0.35.	3.7	0.30	2.5	0	5	15	30	35	35	30	5	0
Japonica Rice (wetland)	120 days	C3/II	0.40	5.0	0.35.	4.0	0.30	2.5	0	5	15	30	35	35	30	5	0
Japonica Rice (wetland)	135 days	C3/II	0.40	5.5	0.35.	4.3	0.30	3.0	0	5	15	30	35	35	30	5	0
Japonica Rice (wetland)	150 days	C3/II	0.40	6.0	0.35.	4.5	0.30	3.0	0	5	15	30	35	35	30	5	0
Indica Rice (wetland)	105 days	C3/II	0.45	5.0	0.38.	3.8	0.30	2.5	0	0	15	30	35	35	30	5	0
Indica Rice (wetland)	120 days	C3/II	0.45	5.5	0.38.	4.0	0.30	2.5	0	0	15	30	35	35	30	5	0
Indica Rice (wetland)	135 days	C3/II	0.45	6.0	0.38.	4.5	0.30	3.0	0	0	15	30	35	35	30	5	0
Indica Rice (wetland)	150 days	C3/II	0.45	6.5	0.38.	4.8	0.30	3.0	0	0	15	30	35	35	30	5	0
Rice (dryland)	105 days	C3/II	0.30	3.5	0.23	2.6	0.15	1.8	0	0	15	30	35	35	30	5	0
Rice (dryland)	120 days	C3/II	0.30	4.0	0.23	3.0	0.15	2.0	0	0	15	30	35	35	30	5	0
Rice (dryland)	135 days	C3/II	0.30	4.5	0.23	3.4	0.15	2.3	0	0	15	30	35	35	30	5	0
Maize (grain) (lowland)	90 days	C4/III	0.40	3.0	0.30	2.3	0.20	1.5	0	0	5	45	65	65	65	45	5
Maize (grain) (lowland)	105 days	C4/III	0.40	3.5	0.30	2.8	0.20	2.0	0	0	5	45	65	65	65	45	5
Maize (grain) (lowland)	120 days	C4/III	0.45	4.0	0.35	3.3	0.25	2.5	0	0	5	45	65	65	65	45	5
Maize (grain) (lowland)	135 days	C4/III	0.45	4.5	0.35	3.3	0.25	2.5	0	0	5	45	65	65	65	45	5
Maize (grain) (highland)	105 days	C4/IV	0.35	3.5	0.25	2.5	0.15	1.5	0	5	40	50	50	50	40	5	0
Maize (grain) (highland)	180 days	C4/IV	0.35	4.0	0.27	3.0	0.20	2.0	0	5	40	50	50	50	40	5	0
Maize (grain) (highland)	300 days	C4/IV	0.35	4.0	0.27	3.0	0.20	2.0	0	5	40	50	50	50	40	5	0

PARAMETERS FOR BIOMASS AND YIELD CALCULATIONS

CROPS	Growth cycle (GC)	Adaptability group	High Inputs		Intermediate Inputs		Low Inputs		Dependence of Rate of Leaf Photosynthesis (Pm) on Temperature (°C)								
			HI	Max. LAI	HI	Max. LAI	HI	Max. LAI	5	10	15	20	25	30	35	40	45
Maize (grain) (sub-tropics)	105 days	C4/IV	0.40	3.0	0.30	2.3	0.20	1.5	0	5	40	50	50	50	40	5	0
Maize (grain) (sub-tropics)	120 days	C4/IV	0.40	3.5	0.30	2.5	0.20	2.0	0	5	40	50	50	50	40	5	0
Maize (grain) (sub-tropics)	135 days	C4/IV	0.45	4.0	0.33	3.0	0.20	2.0	0	5	40	50	50	50	40	5	0
Maize (grain) (sub-tropics)	150 days	C4/IV	0.45	4.5	0.33	3.5	0.20	2.5	0	5	40	50	50	50	40	5	0
Maize (grain) (sub-tropics)	165 days	C4/IV	0.45	5.0	0.35	3.8	0.25	2.5	0	5	40	50	50	50	40	5	0
Maize (grain) (sub-tropics)	180 days	C4/IV	0.45	5.5	0.35	4.3	0.25	3.0	0	5	40	50	50	50	40	5	0
Maize (silage)	105 days	C4/IV	0.60	6.0	0.50	4.5	0.40	3.0	0	5	40	50	50	50	40	5	0
Maize (silage)	120 days	C4/IV	0.60	6.0	0.50	4.5	0.40	3.0	0	5	40	50	50	50	40	5	0
Maize (silage)	135 days	C4/IV	0.60	6.0	0.50	4.5	0.40	3.0	0	5	40	50	50	50	40	5	0
Maize (silage)	150 days	C4/IV	0.65	6.5	0.55	5.0	0.45	3.5	0	5	40	50	50	50	40	5	0
Maize (silage)	165 days	C4/IV	0.65	6.5	0.55	5.0	0.45	3.5	0	5	40	50	50	50	40	5	0
Maize (silage)	180 days	C4/IV	0.65	7.0	0.55	5.5	0.45	4.0	0	5	40	50	50	50	40	5	0
Barley (winter)	30-90 days	C3/I	0.45	4.5	0.35	3.5	0.25	2.5	5	15	25	25	20	10	0	0	0
Barley (winter)	35-105 days	C3/I	0.45	5.0	0.35	3.8	0.25	2.5	5	15	25	25	20	10	0	0	0
Barley (winter)	40-120 days	C3/I	0.50	5.5	0.40	4.0	0.30	2.5	5	15	25	25	20	10	0	0	0
Barley (winter)	45-135 days	C3/I	0.50	5.5	0.40	4.0	0.30	2.5	5	15	25	25	20	10	0	0	0
Barley (spring)	90 days	C3/I	0.40	3.5	0.30	2.8	0.20	2.0	5	15	20	20	15	5	0	0	0
Barley (spring)	105 days	C3/I	0.40	3.5	0.30	2.8	0.20	2.0	5	15	20	20	15	5	0	0	0
Barley (spring)	120 days	C3/I	0.40	4.0	0.30	3.3	0.20	2.5	5	15	20	20	15	5	0	0	0
Barley (spring)	135 days	C3/I	0.40	4.5	0.30	3.5	0.20	2.5	5	15	20	20	15	5	0	0	0
Barley (sub-tropics)	90 days	C3/I	0.45	4.0	0.35	3.0	0.25	2.0	5	15	20	20	15	5	0	0	0
Barley (sub-tropics)	105 days	C3/I	0.45	4.5	0.35	3.3	0.25	2.0	5	15	20	20	15	5	0	0	0
Barley (sub-tropics)	120 days	C3/I	0.45	5.0	0.35	3.8	0.25	2.5	5	15	20	20	15	5	0	0	0
Barley (sub-tropics)	135 days	C3/I	0.45	5.0	0.35	3.8	0.25	2.5	5	15	20	20	15	5	0	0	0
Barley (tropics)	100 days	C3/I	0.40	3.5	0.30	2.5	0.20	1.5	5	15	20	20	15	5	0	0	0
Barley (tropics)	130 days	C3/I	0.40	4.0	0.30	3.0	0.20	2.0	5	15	20	20	15	5	0	0	0
Barley (tropics)	160 days	C3/I	0.40	5.0	0.30	3.8	0.20	2.5	5	15	20	20	15	5	0	0	0
Barley (tropics)	190 days	C3/I	0.40	5.0	0.30	3.8	0.20	2.5	5	15	20	20	15	5	0	0	0
Sorghum (lowland)	90 days	C4/III	0.35	3.5	0.25	2.5	0.15	1.5	0	0	5	45	65	65	65	45	5
Sorghum (lowland)	105 days	C4/III	0.35	4.0	0.25	3.0	0.15	2.0	0	0	5	45	65	65	65	45	5
Sorghum (lowland)	120 days	C4/III	0.35	4.5	0.25	3.3	0.15	2.0	0	0	5	45	65	65	65	45	5
Sorghum (lowland)	135 days	C4/III	0.35	4.5	0.25	3.3	0.15	2.0	0	0	5	45	65	65	65	45	5
Sorghum (highland)	105 days	C4/IV	0.20	3.5	0.16	2.5	0.12	1.5	0	5	40	50	50	50	40	5	0
Sorghum (highland)	180 days	C4/IV	0.20	4.0	0.16	3.0	0.12	2.0	0	5	40	50	50	50	40	5	0
Sorghum (highland)	300 days	C4/IV	0.20	4.0	0.16	3.0	0.12	2.0	0	5	40	50	50	50	40	5	0

PARAMETERS FOR BIOMASS AND YIELD CALCULATIONS

CROPS	Growth cycle (GC)	Adaptability group	High Inputs		Intermediate inputs		Low Inputs		Dependence of Rate of Leaf Photosynthesis (Pm) on Temperature (°C)								
			HI	Max. LAI	HI	Max. LAI	HI	Max. LAI	5	10	15	20	25	30	35	40	45
Rye (winter)	30-90 days	C3/I	0.35	3.5	0.28	2.8	0.20	2.0	5	15	20	20	15	5	0	0	0
Rye (winter)	35-105 days	C3/I	0.35	4.0	0.28	3.0	0.20	2.0	5	15	20	20	15	5	0	0	0
Rye (winter)	40-120 days	C3/I	0.35	4.0	0.28	3.0	0.20	2.0	5	15	20	20	15	5	0	0	0
Rye (winter)	45-135 days	C3/I	0.35	4.5	0.28	3.5	0.20	2.5	5	15	20	20	15	5	0	0	0
Rye (spring)	90 days	C3/I	0.35	3.0	0.25	2.3	0.15	1.5	5	15	20	20	15	5	0	0	0
Rye (spring)	105 days	C3/I	0.35	3.5	0.25	2.5	0.15	1.8	5	15	20	20	15	5	0	0	0
Rye (spring)	120 days	C3/I	0.35	4.0	0.25	3.0	0.15	2.0	5	15	20	20	15	5	0	0	0
Rye (spring)	135 days	C3/I	0.35	4.0	0.25	3.0	0.15	2.0	5	15	20	20	15	5	0	0	0
Pearl Millet	70 days	C4/III	0.25	3.0	0.18	2.3	0.12	1.5	0	0	5	45	65	65	65	45	5
Pearl Millet	90 days	C4/III	0.25	3.5	0.18	2.8	0.12	2.0	0	0	5	45	65	65	65	45	5
Foxtail Millet	75 days	C4/IV	0.30	3.5	0.25	2.6	0.15	1.5	0	5	40	50	50	50	40	5	0
Foxtail Millet	90 days	C4/IV	0.30	4.0	0.25	3.0	0.15	2.0	0	5	40	50	50	50	40	5	0
Foxtail Millet	105 days	C4/IV	0.35	4.5	0.28	3.5	0.20	2.5	0	5	40	50	50	50	40	5	0
Foxtail Millet	120 days	C4/IV	0.35	5.0	0.28	3.8	0.20	2.5	0	5	40	50	50	50	40	5	0
White Potato	90 days	C3/I	0.60	3.5	0.45	2.8	0.30	2.0	5	15	25	25	20	15	5	0	0
White Potato	120 days	C3/I	0.60	4.5	0.45	3.2	0.30	2.0	5	15	25	25	20	15	5	0	0
White Potato	150 days	C3/I	0.60	5.0	0.45	3.7	0.30	2.5	5	15	25	25	20	15	5	0	0
White Potato	180 days	C3/I	0.60	5.5	0.45	4.0	0.30	2.5	5	15	25	25	20	15	5	0	0
Cassava	≤ 365 days	C3/II	0.50	3.0	0.40	2.3	0.30	1.5	0	0	15	30	35	35	30	5	0
Sweet Potato	120 days	C3/II	0.55	4.0	0.42	3.0	0.30	2.0	0	0	15	30	35	35	30	5	0
Sweet Potato	150 days	C3/II	0.55	4.0	0.42	3.0	0.30	2.0	0	0	15	30	35	35	30	5	0
Sweet Potato	180 days	C3/II	0.55	4.5	0.42	3.5	0.30	2.5	0	0	15	30	35	35	30	5	0
Sugarcane	≤ 365 days	C4/III	0.15	7.0	0.12	5.3	0.10	3.5	0	0	5	45	65	65	65	45	5
Sugarbeet	150 days	C3/I	0.15	5.0	0.10	3.5	0.08	2.0	5	15	20	25	25	25	25	5	0
Sugarbeet	165 days	C3/I	0.15	5.5	0.10	4.0	0.08	2.5	5	15	20	25	25	25	25	5	0
Sugarbeet	180 days	C3/I	0.15	5.5	0.10	4.0	0.08	2.5	5	15	20	25	25	25	25	5	0
Sugarbeet	195 days	C3/I	0.15	6.0	0.10	4.5	0.08	3.0	5	15	20	25	25	25	25	5	0
Sugarbeet	210 days	C3/I	0.15	6.0	0.10	4.5	0.08	3.0	5	15	20	25	25	25	25	5	0
Phaseolus Bean (lowland)	90 days	C3/II	0.30	3.5	0.23	2.6	0.15	1.8	0	0	15	30	35	35	30	5	0
Phaseolus Bean (lowland)	120 days	C3/II	0.30	4.0	0.23	3.0	0.15	2.0	0	0	15	30	35	35	30	5	0
Phaseolus Bean (lowland)	150 days	C3/II	0.30	4.0	0.23	3.0	0.15	2.0	0	0	15	30	35	35	30	5	0
Phaseolus Bean (highland)	120 days	C3/I	0.30	4.0	0.23	3.0	0.15	2.0	5	15	25	25	20	15	5	0	0
Phaseolus Bean (highland)	150 days	C3/I	0.30	4.0	0.23	3.0	0.15	2.0	5	15	25	25	20	15	5	0	0
Phaseolus Bean (highland)	180 days	C3/I	0.30	4.0	0.23	3.0	0.15	2.0	5	15	25	25	20	15	5	0	0
Phaseolus Bean (temperate)	90 days	C3/I	0.30	3.0	0.23	2.3	0.15	1.5	5	15	25	25	20	15	5	0	0
Phaseolus Bean (temperate)	120 days	C3/I	0.30	4.0	0.23	3.0	0.15	2.0	5	15	25	25	20	15	5	0	0
Phaseolus Bean (temperate)	150 days	C3/I	0.30	4.0	0.23	3.0	0.15	2.0	5	15	25	25	20	15	5	0	0

PARAMETERS FOR BIOMASS AND YIELD CALCULATIONS

CROPS	Growth cycle (GC)	Adaptability group	High Inputs		Intermediate Inputs		Low Inputs		Dependence of Rate of Leaf Photosynthesis (Pm) on Temperature (°C)								
			HI	Max. LAI	HI	Max. LAI	HI	Max. LAI	5	10	15	20	25	30	35	40	45
Chickpea	90 days	C3/I	0.30	3.0	0.23	2.3	0.15	1.5	0	5	15	30	35	35	30	5	0
Chickpea	105 days	C3/I	0.30	3.5	0.23	2.7	0.15	1.8	0	5	15	30	35	35	30	5	0
Chickpea	120 days	C3/I	0.30	4.0	0.23	3.0	0.15	2.0	0	5	15	30	35	35	30	5	0
Chickpea (CR)	150 days	C3/I	0.30	4.0	0.23	3.0	0.15	2.0	0	5	15	30	35	35	30	5	0
Chickpea (CR)	180 days	C3/I	0.30	4.0	0.23	3.0	0.15	2.0	0	5	15	30	35	35	30	5	0
Cowpea	80 days	C3/II	0.30	3.0	0.23	2.3	0.15	1.5	0	0	15	30	35	35	30	5	0
Cowpea	100 days	C3/II	0.30	3.5	0.23	2.7	0.15	1.8	0	0	15	30	35	35	30	5	0
Cowpea	120 days	C3/II	0.30	4.0	0.23	3.0	0.15	2.0	0	0	15	30	35	35	30	5	0
Groundnut	90 days	C3/II	0.30	3.0	0.23	2.3	0.15	1.5	0	0	15	30	35	35	30	5	0
Groundnut	105 days	C3/II	0.30	3.5	0.23	2.7	0.15	1.8	0	0	15	30	35	35	30	5	0
Groundnut	120 days	C3/II	0.30	4.0	0.23	3.0	0.15	2.0	0	0	15	30	35	35	30	5	0
Soybean (tropics)	90 days	C3/II	0.30	3.0	0.23	2.3	0.15	1.5	0	0	15	30	35	35	30	5	0
Soybean (tropics)	105 days	C3/II	0.30	3.5	0.23	2.7	0.15	1.8	0	0	15	30	35	35	30	5	0
Soybean (tropics)	120 days	C3/II	0.30	4.0	0.23	3.0	0.15	2.0	0	0	15	30	35	35	30	5	0
Soybean (sub-tropics)	105 days	C3/II	0.30	3.5	0.23	2.7	0.15	1.8	0	5	15	30	35	35	30	5	0
Soybean (sub-tropics)	120 days	C3/II	0.30	4.0	0.23	3.0	0.15	2.0	0	5	15	30	35	35	30	5	0
Soybean (sub-tropics)	135 days	C3/II	0.30	4.0	0.23	3.0	0.15	2.0	0	5	15	30	35	35	30	5	0
Sunflower (tropics)	135 days	C3/II	0.25	4.0	0.20	3.0	0.15	2.0	0	0	15	30	35	35	30	5	0
Sunflower (tropics)	150 days	C3/II	0.25	4.5	0.20	3.5	0.15	2.5	0	0	15	30	35	35	30	5	0
Sunflower (tropics)	165 days	C3/II	0.25	5.0	0.20	3.8	0.15	2.5	0	0	15	30	35	35	30	5	0
Sunflower (sub tropics)	135 days	C3/I	0.25	4.0	0.20	3.0	0.15	2.0	5	15	25	25	20	15	5	0	0
Sunflower (sub tropics)	150 days	C3/I	0.25	4.5	0.20	3.5	0.15	2.5	5	15	25	25	20	15	5	0	0
Sunflower (sub tropics)	165 days	C3/I	0.25	5.0	0.20	3.8	0.15	2.5	5	15	25	25	20	15	5	0	0
Rape (winter)	35-105 days	C3/I	0.25	3.5	0.18	2.5	0.12	1.5	5	15	25	25	20	15	5	0	0
Rape (winter)	45-120 days	C3/I	0.25	4.0	0.18	3.0	0.12	2.0	5	15	25	25	20	15	5	0	0
Rape (spring)	135 days	C3/I	0.25	3.5	0.18	2.5	0.12	1.5	5	15	25	25	20	15	5	0	0
Rape (spring)	150 days	C3/I	0.25	4.0	0.18	3.0	0.12	2.0	5	15	25	25	20	15	5	0	0
Rape (spring)	165 days	C3/I	0.25	4.0	0.18	3.0	0.12	2.0	5	15	25	25	20	15	5	0	0
Rape (sub-tropics/tropics)	135 days	C3/I	0.25	3.5	0.18	2.5	0.12	1.5	5	15	20	25	25	25	25	5	0
Rape (sub-tropics/tropics)	150 days	C3/I	0.25	4.0	0.18	3.0	0.12	2.0	5	15	20	25	25	25	25	5	0
Rape (sub-tropics/tropics)	165 days	C3/I	0.25	4.0	0.18	3.0	0.12	2.0	5	15	20	25	25	25	25	5	0
Oil palm	≤ 365 days	C3/II	0.20	6.0	0.15	4.5	0.10	3.0	0	0	15	30	35	35	30	5	0
Olive	≤ 365 days	C3/I	0.20	3.5	0.15	2.5	0.10	1.5	5	15	20	25	25	25	25	5	0
Banana/Plantain	≤ 365 days	C3/II	0.25	6.0	0.20	4.5	0.15	3.0	0	0	15	30	35	35	30	5	0

PARAMETERS FOR BIOMASS AND YIELD CALCULATIONS

CROPS	Growth cycle (GC)	Adaptability group	High Inputs		Intermediate Inputs		Low Inputs		Dependence of Rate of Leaf Photosynthesis (Pm) on Temperature (°C)								
			HI	Max. LAI	HI	Max. LAI	HI	Max. LAI	5	10	15	20	25	30	35	40	45
Cotton (tropics)	135 days	C3/II	0.07	2.5	0.05	2.0	0.03	1.5	0	0	15	30	35	35	30	5	0
Cotton (tropics)	150 days	C3/II	0.07	2.5	0.05	2.0	0.03	1.5	0	0	15	30	35	35	30	5	0
Cotton (tropics)	165 days	C3/II	0.07	3.0	0.05	2.5	0.03	2.0	0	0	15	30	35	35	30	5	0
Cotton (tropics)	180 days	C3/II	0.07	3.0	0.05	2.5	0.03	2.0	0	0	15	30	35	35	30	5	0
Cotton (sub-tropics)	135 days	C3/II	0.07	2.5	0.05	2.0	0.03	1.5	0	0	15	30	35	35	30	5	0
Cotton (sub-tropics)	150 days	C3/II	0.07	2.5	0.05	2.0	0.03	1.5	0	0	15	30	35	35	30	5	0
Cotton (sub-tropics)	165 days	C3/II	0.07	3.0	0.05	2.5	0.03	2.0	0	0	15	30	35	35	30	5	0
Alfalfa	≤ 365 days	C3/I	0.65	6.0	0.45	4.5	0.25	3.0	5	15	20	25	25	25	25	5	0
Grass + Legume (temp.)	≤ 365 days	C3/I	0.65	4.0	0.40	3.0	0.30	2.5	5	15	20	20	15	5	0	0	0
Grass + Legume (tropics)	≤ 365 days	C3/II	0.65	4.0	0.40	3.0	0.30	2.5	2.5	10	20	25	25	20	10	5	0
Grasses (temp.)	≤ 365 days	C3/I	0.65	4.0	0.40	3.0	0.30	2.5	5	15	20	20	15	5	0	0	0
Grasses (tropics)	≤ 365 days	C3/II	0.65	4.0	0.40	3.0	0.30	2.5	0	2.5	15	35	37.5	37.5	30	5	0
Grasses (temp.)	≤ 365 days	C4/IV	0.65	4.0	0.40	3.0	0.30	2.5	2.5	15	37.5	50	50	37.5	25	10	0
Grassess (tropics)	≤ 365 days	C4/III	0.65	4.0	0.40	3.0	0.30	2.5	0	2.5	30	40	47.5	50	47.5	40	5

- Main Sources:**
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 - Heemst H.D.J. van, 1988.** Plant data values required for simple crop growth simulation models: review and bibliography. Simulation Report Cabo-TT Centre for Agrobiological Research (CABO) and Department of Theoretical Production Ecology, Agricultural University Wageningen, 100p.
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Notes: When the growth cycle is curtailed due to the growing period being shorter, both harvest index *and* maximum leaf area index are to be reduced proportionately relative to the normal yield formation period.

It is assumed that yield formation periods relate to growth cycles as follows: cereals 33%; roots and tubers 66%; legumes 50%; oil crops except for olive and oil palm 50%; fiber crops 50%. sugar crops 66%; and pastures 100%. The yield formation period of winter crops is relative to the post-winter (dormancy) part of the growth cycle.

PARAMETERS FOR CALCULATION OF WATER-LIMITED YIELDS

CROPS	Length of Crop Stage (% of growth cycle)				Crop water requirements relative to reference evapotranspiration				Yield loss factors				
	$d1$	$d2$	$d3$	$d4$	$k1^c$	$k2^c$	$k3^c$	$k0^c$	k_1^y	k_2^y	k_3^y	k_4^y	k_0^y
Wheat (winter)	10	30	35	25	0.40	1.10	0.40	0.85	0.20	0.60	0.75	0.50	1.05
Wheat (spring)	10	20	45	25	0.40	1.10	0.40	0.85	0.20	0.65	0.80	0.55	1.15
Rice (wetland)	10	30	30	30	1.10	1.20	1.00	1.10	1.00	2.00	2.50	1.00	2.00
Rice (dryland)	10	30	30	30	0.50	1.20	0.60	0.90	0.40	0.90	1.50	0.50	1.25
Maize /grain)	15	30	35	20	0.40	1.10	0.60	0.85	0.40	0.90	1.50	0.50	1.25
Barley (winter)	10	30	35	25	0.40	1.10	0.40	0.85	0.20	0.60	0.75	0.50	1.05
Barley (spring)	10	20	45	25	0.40	1.10	0.40	0.85	0.20	0.65	0.80	0.55	1.15
Sorghum	10	25	40	25	0.40	1.05	0.55	0.80	0.20	0.60	0.90	0.50	0.90
Rye (winter)	10	30	35	25	0.40	1.10	0.40	0.85	0.20	0.60	0.75	0.50	1.05
Rye (spring)	10	20	45	25	0.40	1.10	0.40	0.85	0.20	0.65	0.80	0.55	1.15
Pearl Millet	10	25	40	25	0.35	1.05	0.40	0.80	0.20	0.60	0.80	0.50	0.90
Foxtail Millet	10	25	40	25	0.40	1.05	0.40	0.85	0.20	0.60	0.80	0.50	1.00
White Potato	20	25	35	20	0.50	1.10	0.75	0.85	0.50	0.80	0.80	0.70	1.10
Sweet Potato	20	25	35	20	0.50	1.10	0.75	0.85	0.50	0.80	0.80	0.70	1.10
Sugarbeet	15	30	35	20	0.50	1.10	0.70	0.85	1.00	1.00	1.00	0.50	1.10
Phaseolous Bean	20	33	33	14	0.40	1.10	0.90	0.85	0.20	0.60	1.10	0.75	1.15
Chickpea	20	33	33	14	0.40	1.10	0.70	0.85	0.20	0.60	1.10	0.75	1.15
Cowpea	20	33	33	14	0.40	1.10	0.70	0.85	0.20	0.60	1.10	0.75	1.15
Groundnut	20	30	30	20	0.50	1.05	0.60	0.80	0.20	0.80	0.80	0.60	0.70
Soybean	15	20	45	20	0.40	1.10	0.50	0.85	0.20	0.80	1.00	0.80	0.85
Sunflower	17	28	35	20	0.40	1.10	0.40	0.80	0.25	0.60	1.00	0.80	0.95
Rape	15	25	40	20	0.50	1.10	0.50	0.80	0.20	0.80	1.00	0.80	0.85
Cotton	15	30	30	25	0.50	1.15	0.70	0.85	0.20	0.50	0.75	0.50	0.85

Notes: The coefficients $d1, \dots, d4$ relate to the characteristics of the crop growth cycle, denoting here the relative length (in percent) of four crop development stages, namely, initial stage, vegetative stage, reproductive stage, and maturation stage. Parameters $k1^c, k2^c,$ and $k3^c$ define crop water requirements respectively for the initial stage, the reproductive phase, and the end of the maturation stage. Coefficient $k0^c$ indicates water requirements relative to reference evapotranspiration over the entire growth cycle. Finally, factors k^y quantify the expected yield loss in relation to a crop evapotranspiration deficit, by crop stage and for the entire growth cycle, respectively. For calculation details, see Appendix 6.

APPENDIX VIII

AGRO-CLIMATIC CONSTRAINT RATINGS

Agro-climatic constraints cause direct or indirect losses in the yield and quality of produce. Yields losses in a rain-fed crop due to agro-climatic constraints have been formulated based on principles and procedures proposed in FAO1978-81a. Details of the conditions that are influencing yield losses are listed below.

(i) *How well the crop growth cycle fits within the length of growing period*

When the growing period is shorter than the growth cycle of the crop, from sowing to full maturity, there is loss of yield. The biomass and yield calculations account for direct losses by appropriately adjusting LAI and harvest index (see section 4.3.2). However, the loss in the marketable value of the produce due to poor quality of the yield as influenced by incomplete yield formation (e.g., incomplete grain filling in grain crops resulting in shriveled grains or yield of a lower grade, incomplete bulking in root and tuber leading to a poor grade of ware), is not accounted for in the biomass and yield calculations. This loss is to be considered as an agro-climatic constraint in addition to the quantitative yield loss due to curtailment of the yield formation period. Yield losses can also occur when the length of the growing period is much longer than the length of the growth cycles. These losses operate through yield and quality reducing effects of (i) pests, diseases and weeds, (ii) climatic factors affecting yield components and yield formation, and (iii) climatic conditions affecting the efficiency of farming operations.

(ii) *The degree of water-stress during the growing period*

Water-stress generally affects crop growth, yield formation and quality of produce. The yield reducing effects of water-stress varies from crop to crop. The total yield impact can be considered in terms of (i) the effect on growth of the whole crop, and (ii) the effect on yield formation and quality of produce. For some crops, the latter effect can be more severe than the former, particularly where the yield is a reproductive part (e.g., cereals) and yield formation depends on the sensitivity of floral parts and fruit set to water-stress (e.g., silk drying in maize).

(iii) *Pests, diseases and weeds*

To assess the agro-climatic constraints of pest, disease and weed complex, it is convenient to separate the effects on yields that operate through loss in crop growth potential (e.g., pest and diseases affecting vegetative parts in grain crops) from effects on yield that operate directly on yield formation and quality of produce (e.g., cotton stainer affecting lint quality, grain mould in sorghum affecting both yield and grain quality).

(iv) *Climatic factors directly or indirectly reducing yield and quality of produce*

These include problems of poor seed set and/or maturity under cool or low temperature conditions, problems of seed germination in the panicle due to wet conditions at the end of grain filling, problems of poor quality lint due to wet conditions during the time of boll opening period in cotton, problems of poor seed set in wet conditions at the time of flowering in some grain crops, and problems of excessive vegetative growth and poor harvest index due to high night-time temperature or low diurnal range in temperature.

(v) *Climatic factors affecting the efficiency of farming operations and costs of production*

Farming operations include those related to land preparation, sowing, cultivation and crop protection during crop growth, and harvesting (including operations related to handling the produce during harvest and the effectiveness of being able to dry the produce). Agro-climatic constraints in this category are essentially workability constraints, which primarily account for excessive wetness conditions. Limited workability can cause direct losses in yield and quality of produce, and/or impart a degree of relative unsuitability to an area for a given crop from the point of view of how effectively crop cultivation and produce handling can be conducted at a given level of inputs.

(vi) *Frost hazard and extreme temperature events*

The risk of occurrence of late and early frost increases substantially when mean temperatures drop below 10°C. Hence, length of the thermal growing period with temperatures above 10°C (LGPT10) in a grid-cell has been compared with growth cycle length of frost sensitive crops. When the crop growth cycle is slightly shorter than LGPT10 the constraints related to frost risk are adjudged moderate, when the growth cycle is very close or equal to LGPT10, the constraints have been adjudged as severe.

The agro-climatic constraints described above are closely related to prevailing climate conditions. For convenience they have been arranged in five groups as follows:

- (a) yield losses due to water-stress constraints on crop growth (e.g., rainfall variability);
- (b) yield losses due to the effect of pests, diseases and weed constraints on crop growth;
- (c) yield losses due to water stress, pest and diseases constraints on yield components and yield formation of produce (e.g., affecting quality of produce);
- (d) yield losses due to workability constraints (e.g., wetness rendering produce handling difficulties), and
- (e) yield losses due to occurrence of early or late frosts.

At the stage of computing potential biomass and yields, no account is taken of the effects of climatic conditions operating through pests and diseases, and workability. Such effects need to be included to arrive at realistic attainable crop yields. Precise estimates of their impacts are very difficult to obtain for a global study. Here it has been achieved by semi-quantifying the constraints in terms of reduction ratings, according to the different constraints and their severity for each crop, in each length of growing period zone and by level of inputs. The latter subdivision is necessary to take account of the fact that some constraints, such as bollworm on cotton, are present under low input conditions but are controllable under high input conditions in certain growing period zones. While some constraints are common to all input levels, others (e.g., poor workability through excess moisture) are more applicable to high input conditions with mechanized cultivation.

Although the constraints of group 'd' are not direct yield losses in reality, such constraints do mean, for example, that the high input level mechanized cultivator cannot get onto the land to carry out operations. In practice, these results in yield reductions. Similarly for the low input cultivator, for example, excessive wetness could mean that the produce is too wet to handle and remove, and again losses would be incurred even though the produce may be standing in the field. Also included in this group are constraints due to the cultivator having to use longer duration cultivars to enable harvesting in dry conditions. The use of such cultivars incurs yield restrictions, and such circumstances under wet conditions have therefore been incorporated in the severity ratings of agro-climatic constraints in group 'd'.

In general, with increasing length of growing period and wetness, constraints due to pests and diseases (groups 'b' and 'c') become increasingly severe particularly to low input cultivators. As the length of growing period gets very long, even the high input level cultivator cannot keep these constraints under control and they become severe yield reducing factors at all three levels of inputs. Other factors, such as poor pod set in soybean or poor quality in short lengths of growing period zones, are of similar severity for all three levels of inputs. Difficulties in lifting root crops under dry soil conditions (short lengths of growing periods group 'd') are rated more severely under the high level of inputs (mechanized) than under intermediate and low level of inputs. For irrigated production the 'c' constraint is applied only at the wet end, i.e., above 300 days in the example of Table 9 (in Chapter 4).

Input level:

1 = low input level, 2 = intermediate input level, 3 = high input level

Constraint type:

- 1 = 'a' constraint, yield losses due to water-stress constraints on crop growth (e.g., rainfall variability);
- 2 = 'b' constraint, yield losses due to the effect of pests, diseases and weed constraints on crop growth;
- 3 = 'c' constraint, yield losses due to water-stress, pest and diseases constraints on yield components and yield formation of produce;
- 4 = 'd' constraint, yield losses due to workability constraints (e.g., wetness rendering produce handling difficulties);
- 5 = 'e' constraint, yield losses due to occurrence of early or late frosts.

AGRO-CLIMATIC CONSTRAINTS

Crop	Growth cycle	Input level	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
WINTER WHEAT	30+90 d	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	30+90 d	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	30+90 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	30+90 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	30+90 d	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	30+90 d	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	30+90 d	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	30+90 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	30+90 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	30+90 d	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	30+90 d	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	30+90 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	30+90 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	30+90 d	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	30+90 d	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	35+105 d	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	35+105 d	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	35+105 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	35+105 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	35+105 d	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	35+105 d	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	35+105 d	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	35+105 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	35+105 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	35+105 d	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	35+105 d	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	35+105 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	35+105 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	35+105 d	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	35+105 d	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	40+120 d	1	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	40+120 d	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	40+120 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	40+120 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	40+120 d	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	40+120 d	2	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	40+120 d	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	40+120 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	40+120 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	40+120 d	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
40+120 d	3	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0	
40+120 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
40+120 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
40+120 d	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
40+120 d	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input level	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
WINTER WHEAT	45+135 d	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	45+135 d	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	45+135 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	45+135 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	45+135 d	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	45+135 d	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	45+135 d	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	45+135 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	45+135 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	45+135 d	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	45+135 d	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	45+135 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	45+135 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	45+135 d	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	45+135 d	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
SPRING WHEAT	105 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	105 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	105 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	105 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	105 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	105 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	105 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	105 days	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	120 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	120 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	120 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	120 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	120 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	120 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0

Crop	Growth cycle	Input level	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SPRING WHEAT	135 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	135 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	135 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	135 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	135 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	135 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	135 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	135 days	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	150 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	150 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	150 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	150 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	150 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	150 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	150 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	150 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	150 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	150 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	150 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	150 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
WHEAT, SUB-TROPICS	105 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	
	105 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	
	105 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	105 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	105 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	105 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	105 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	105 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	105 days	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0

Crop	Growth cycle	Input Levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
WHEAT, SUB-TROPICS	120 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	120 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	120 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	120 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	120 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	120 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	135 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	135 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	135 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	135 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	135 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	135 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	135 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	135 days	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	150 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	150 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	150 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	150 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	150 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	150 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	150 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	150 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
150 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0	
150 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
150 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
150 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
150 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
WHEAT, TROPICS	100 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	100 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	100 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	100 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	100 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	100 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	100 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	100 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	100 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	100 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	100 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	100 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	130 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	130 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	130 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	130 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	130 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	130 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	130 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	130 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	130 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	130 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	130 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	130 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	160 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	160 days	1	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	160 days	1	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	160 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	160 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	160 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	160 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	160 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	160 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	160 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	160 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	160 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	190 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	190 days	1	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	190 days	1	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	190 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
190 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0	
190 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
190 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50	
190 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
190 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0	
190 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
190 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
190 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
RICE, JAPONICA	105 days	1	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	105 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	105 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	105 days	2	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	105 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	105 days	3	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	105 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25
	105 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	105 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	120 days	1	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	120 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	120 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	120 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	120 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25
	120 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	135 days	1	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	135 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	135 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	1	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0
	135 days	2	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	135 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25
	135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	2	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0
135 days	3	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25	
135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
135 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25	
135 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
135 days	3	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
RICE, JAPONICA	150 days	1	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	150 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	150 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	150 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	150 days	1	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0
	150 days	2	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	150 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25
	150 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	150 days	2	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0
	150 days	3	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	150 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25
	150 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	150 days	3	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0
RICE, INDICA	105 days	1	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	105 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	105 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	2	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	105 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	3	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	105 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25
	105 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	1	1	100	100	100	100	100	100	100	100	50	50	50	25	25	25	25
	120 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	120 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	2	1	100	100	100	100	100	100	100	100	50	50	50	25	25	25	25
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	120 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	3	1	100	100	100	100	100	100	100	100	50	50	50	25	25	25	25
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	120 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25
	120 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	135 days	1	1	100	100	100	100	100	100	100	100	50	50	50	25	25	25	25
	135 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	135 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	2	1	100	100	100	100	100	100	100	100	50	50	50	25	25	25	25
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
135 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25	
135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
RICE, INDICA	135 days	3	1	100	100	100	100	100	100	100	50	50	25	25	25	25	25	
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	135 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	
	135 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	150 days	1	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	150 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	150 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	150 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	150 days	2	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	150 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25
	150 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	150 days	3	1	100	100	100	100	100	100	100	50	50	50	25	25	25	25	25
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	150 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25
150 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
RICE, DRYLAND	105 days	1	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	
	105 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	25	
	105 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	2	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	105 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	3	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	105 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25
	105 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	1	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	120 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	2	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	120 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	3	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	120 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25
	120 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	135 days	1	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0
	135 days	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	135 days	1	3	50	50	50	50	50	50	25	25	0	0	0	25	25	25	25
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	2	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
135 days	2	3	50	50	50	50	50	50	25	25	0	0	0	0	25	25	25	
135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
RICE, DRYLAND	135 days	3	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	135 days	3	3	50	50	50	50	50	50	25	25	0	0	0	0	0	25	25
	135 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
MAIZE (GRAIN), TROPICAL LOWLAND	90 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	1	2	25	25	25	25	25	25	0	0	25	25	25	25	25	25	50
	90 days	1	3	50	50	50	50	25	0	0	0	0	0	0	25	25	25	50
	90 days	1	4	0	0	0	0	0	0	0	0	25	25	25	50	50	50	50
	90 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	90 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	90 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	90 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	90 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	90 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	105 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	1	2	25	25	25	25	25	25	0	0	25	25	25	25	25	25	50
	105 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	105 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	105 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	105 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	105 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	105 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	105 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	25	25	25	25	25	25	0	0	25	25	25	25	25	25	50
	120 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	120 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	120 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	120 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	120 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	135 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	1	2	25	25	25	25	25	25	0	0	25	25	25	25	25	25	50
	135 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	135 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	25	50
135 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
135 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50	
135 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50	
135 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
MAIZE (GRAIN), TROPICAL LOWLAND	135 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	135 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50	
	135 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50	
	135 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
MAIZE (GRAIN), TROPICAL HIGHLAND	105 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	105 days	1	2	25	25	25	25	25	25	0	0	25	25	25	25	25	25	50	
	105 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50	
	105 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
	105 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	105 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50	
	105 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25	50
	105 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
	105 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	105 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50	
	105 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25	50
	105 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
	180 days	1	1	100	100	100	50	50	50	25	25	0	0	0	0	0	0	0	
	180 days	1	2	25	25	25	25	25	25	0	0	0	0	25	25	25	25	50	
	180 days	1	3	50	50	50	50	50	50	25	0	0	0	0	0	0	25	25	50
	180 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	180 days	2	1	100	100	100	50	50	50	25	25	0	0	0	0	0	0	0	
	180 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	180 days	2	3	50	50	50	50	50	50	25	0	0	0	0	0	0	25	25	50
	180 days	2	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	180 days	3	1	100	100	100	50	50	50	25	25	0	0	0	0	0	0	0	
	180 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	180 days	3	3	50	50	50	50	50	50	25	0	0	0	0	0	0	25	25	50
	180 days	3	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	300 days	1	1	100	100	100	50	50	50	50	50	50	50	25	0	0	0	0	
	300 days	1	2	25	25	25	25	25	25	0	0	0	0	25	25	25	25	50	
	300 days	1	3	50	50	50	50	50	50	50	50	25	25	0	0	25	25	50	
	300 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50	
	300 days	2	1	100	100	100	50	50	50	50	50	50	50	25	0	0	0	0	
	300 days	2	2	0	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	300 days	2	3	50	50	50	50	50	50	50	50	25	25	0	0	25	25	50	
	300 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	300 days	3	1	100	100	100	50	50	50	50	50	50	50	25	0	0	0	0	
	300 days	3	2	0	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	300 days	3	3	50	50	50	50	50	50	50	50	25	25	0	0	25	25	50	
	300 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
MAIZE (GRAIN), SUBTROP./TEMPER.	105 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0		
	105 days	1	2	0	0	0	0	0	0	0	0	25	25	25	25	25	50		
	105 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50	
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	105 days	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0		
	105 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0		
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
	105 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
MAIZE (GRAIN), SUBTROP./TEMPER..	105 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	105 days	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	105 days	3	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	105 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	105 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	105 days	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	120 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	25	25	25	25	25	25	50
	120 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	120 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	120 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	120 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	120 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	135 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	1	2	0	0	0	0	0	0	0	0	25	25	25	25	25	25	50
	135 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	135 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	135 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	135 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	135 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	135 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	135 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
	135 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	135 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	150 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	0	25	25	25	25	25	25	50
	150 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50
150 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50	
150 days	1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	
150 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
150 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
150 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50	
150 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50	
150 days	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
MAIZE (GRAIN), SUBTROP./TEMPER.	150 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
	150 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	25	25	50	
	150 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	150 days	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	
	165 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	165 days	1	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
	165 days	1	3	50	50	50	50	50	25	0	0	0	0	0	0	25	25	50	
	165 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50	
	165 days	1	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0	
	165 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	165 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
	165 days	2	3	50	50	50	50	50	25	0	0	0	0	0	0	25	25	50	
	165 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	165 days	2	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0	
	165 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	165 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
	165 days	3	3	50	50	50	50	50	25	0	0	0	0	0	0	25	25	50	
	165 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	165 days	3	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0	
	180 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	180 days	1	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
	180 days	1	3	50	50	50	50	50	25	0	0	0	0	0	0	25	25	50	
	180 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50	
	180 days	1	5	100	100	100	100	100	100	50	0	0	0	0	0	0	0	0	
	180 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	180 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
	180 days	2	3	50	50	50	50	50	25	0	0	0	0	0	0	25	25	50	
	180 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	180 days	2	5	100	100	100	100	100	100	50	0	0	0	0	0	0	0	0	
180 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0		
180 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50		
180 days	3	3	50	50	50	50	50	25	0	0	0	0	0	0	25	25	50		
180 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50		
180 days	3	5	100	100	100	100	100	100	50	0	0	0	0	0	0	0	0		
MAIZE (SILAGE)	105 days	1	1	100	100	100	25	0	0	0	0	0	0	0	0	0	0	0	
	105 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50	
	105 days	1	3	50	50	50	25	0	0	0	0	0	0	0	0	0	25	25	
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
	105 days	1	5	100	100	100	50	0	0	0	0	0	0	0	0	0	0	0	
	105 days	2	1	100	100	100	25	0	0	0	0	0	0	0	0	0	0	0	
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50	
	105 days	2	3	50	50	50	25	0	0	0	0	0	0	0	0	0	25	25	
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
	105 days	2	5	100	100	100	50	0	0	0	0	0	0	0	0	0	0	0	
	105 days	3	1	100	100	100	25	0	0	0	0	0	0	0	0	0	0	0	
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
105 days	3	3	50	50	50	25	0	0	0	0	0	0	0	0	0	25	25		

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
MAIZE (SILAGE)	105 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	105 days	3	5	100	100	100	50	0	0	0	0	0	0	0	0	0	0	0
	120 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	120 days	1	3	50	50	50	25	0	0	0	0	0	0	0	0	0	25	25
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	1	5	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	120 days	2	3	50	50	50	25	0	0	0	0	0	0	0	0	0	25	25
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	2	5	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	3	3	50	50	50	25	0	0	0	0	0	0	0	0	0	25	25
	120 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	120 days	3	5	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	135 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	135 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	135 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	135 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25
	135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	135 days	3	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	135 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25
	135 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	135 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	150 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	150 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25
	150 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	150 days	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	150 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	150 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25
150 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
150 days	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0	
150 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
150 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
150 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25	
150 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
150 days	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
MAIZE (SILAGE)	165 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	165 days	1	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	165 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25	50
	165 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	165 days	1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	165 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	0
	165 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	165 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25	50
	165 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	165 days	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	165 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	0
	165 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	165 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25	50
	165 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	165 days	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	180 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	0
	180 days	1	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	180 days	1	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25	50
	180 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	180 days	1	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	180 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	0
	180 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	180 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25	50
	180 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	180 days	2	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	180 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	0
	180 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	180 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	0	25	25	50
	180 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	180 days	3	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
WINTER BARLEY	30+90 d	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0	
	30+90 d	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	30+90 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50	50
	30+90 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	30+90 d	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0	0
	30+90 d	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0	0
	30+90 d	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	30+90 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50	50
	30+90 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	30+90 d	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0	0
	30+90 d	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0	0
	30+90 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	30+90 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	50
	30+90 d	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	30+90 d	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0	0

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
WINTER BARLEY	35+105 d	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	35+105 d	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	35+105 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	35+105 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	35+105 d	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	35+105 d	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	35+105 d	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	35+105 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	35+105 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	35+105 d	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	35+105 d	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	35+105 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	35+105 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	35+105 d	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	35+105 d	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	40+120 d	1	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	40+120 d	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	40+120 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	40+120 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	40+120 d	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	40+120 d	2	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	40+120 d	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	40+120 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	40+120 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	40+120 d	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	40+120 d	3	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	40+120 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	40+120 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	40+120 d	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	40+120 d	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	45+135 d	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	45+135 d	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	45+135 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	45+135 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	45+135 d	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
45+135 d	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
45+135 d	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25	
45+135 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50	
45+135 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
45+135 d	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	
45+135 d	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
45+135 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
45+135 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
45+135 d	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
45+135 d	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SPRING BARLEY	90 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	90 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	90 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	90 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	90 days	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	90 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	90 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	90 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	90 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	90 days	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	90 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	90 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	90 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	90 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	90 days	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	105 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	105 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	105 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	105 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	105 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	105 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	105 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	105 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	105 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	120 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	120 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	120 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
120 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
120 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
120 days	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
SPRING BARLEY	135 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0	
	135 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25	
	135 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50	
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
	135 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	
	135 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0	
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25	
	135 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50	
	135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
	135 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	
	135 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0	
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
	135 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
	135 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	135 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	
BARLEY, SUB-TROPICS	90 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0	
	90 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25	
	90 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50	
	90 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
	90 days	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0	
	90 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0	
	90 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25	
	90 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50	
	90 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
	90 days	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0	
	90 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0	
	90 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
	90 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
	90 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	90 days	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0	
	105 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0	
	105 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25	
	105 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50	
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
	105 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0	
	105 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0	
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25	
	105 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50	
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
	105 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0	
	105 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0	
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
	105 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
	105 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	105 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
BARLEY, SUB-TROPICS	120 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	120 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	120 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	120 days	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	120 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	120 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	120 days	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	135 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	135 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	135 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	135 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	135 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	135 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	135 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	135 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	135 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
BARLEY, TROPICS	100 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	
	100 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	100 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	100 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	100 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	100 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	100 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	100 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	100 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	100 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	100 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	100 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
BARLEY, TROPICS	130 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	130 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	130 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	130 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	130 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	130 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	130 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	130 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	130 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	130 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	130 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	130 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	160 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	160 days	1	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	160 days	1	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	160 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	160 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	160 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	160 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	160 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	160 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	160 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	160 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	160 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	190 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	190 days	1	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	190 days	1	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	190 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	190 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	190 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
190 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50	
190 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50	
190 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0	
190 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
190 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
190 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
SORGHUM, LOWLAND	90 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	90 days	1	2	25	25	25	25	25	25	0	0	25	25	50	50	50	50	
	90 days	1	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	
	90 days	1	4	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
	90 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	90 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	
	90 days	2	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	
	90 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	90 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	90 days	3	2	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	90 days	3	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	
	90 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SORGHUM, LOWLAND	105 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	1	2	25	25	25	25	25	25	0	0	25	25	50	50	50	50	50
	105 days	1	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	105 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	105 days	2	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	105 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	105 days	3	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	105 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	25	25	25	25	25	25	0	0	25	25	50	50	50	50	50
	120 days	1	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	120 days	2	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	120 days	3	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	120 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	135 days	1	1	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	135 days	1	2	25	25	25	25	25	25	0	0	25	25	50	50	50	50	50
	135 days	1	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	135 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	135 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
135 days	2	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50	
135 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
135 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
135 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
135 days	3	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50	
135 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
SORGHUM, HIGHLAND	105 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	105 days	1	2	25	25	25	25	25	25	0	0	25	25	50	50	50	50	50
	105 days	1	3	50	50	50	25	0	0	0	0	25	50	50	50	50	50	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	105 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	105 days	2	3	50	50	50	25	0	0	0	0	25	50	50	50	50	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	105 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	105 days	3	3	50	50	50	25	0	0	0	0	25	50	50	50	50	50	50
105 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SORGHUM, HIGHLAND	180 days	1	1	100	100	100	50	50	50	25	25	0	0	0	0	0	0	0
	180 days	1	2	25	25	25	25	25	25	0	0	0	25	25	50	50	50	50
	180 days	1	3	50	50	50	50	50	50	25	0	0	0	25	50	50	50	50
	180 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	180 days	2	1	100	100	100	50	50	50	25	25	0	0	0	0	0	0	0
	180 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	180 days	2	3	50	50	50	50	50	50	25	0	0	0	25	50	50	50	50
	180 days	2	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50
	180 days	3	1	100	100	100	50	50	50	25	25	0	0	0	0	0	0	0
	180 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	180 days	3	3	50	50	50	50	50	50	25	0	0	0	25	50	50	50	50
	180 days	3	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50
	300 days	1	1	100	100	100	50	50	50	50	50	50	50	25	0	0	0	0
	300 days	1	2	25	25	25	25	25	25	0	0	0	0	0	25	50	50	50
	300 days	1	3	50	50	50	50	50	50	50	50	50	25	25	25	50	50	50
	300 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	300 days	2	1	100	100	100	50	50	50	50	50	50	50	25	0	0	0	0
	300 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	300 days	2	3	50	50	50	50	50	50	50	50	50	25	25	25	50	50	50
	300 days	2	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
300 days	3	1	100	100	100	50	50	50	50	50	50	50	25	0	0	0	0	
300 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50	
300 days	3	3	50	50	50	50	50	50	50	50	50	25	25	25	50	50	50	
300 days	3	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
WINTER RYE	30+90 d	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	30+90 d	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	30+90 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	30+90 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	30+90 d	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	30+90 d	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	30+90 d	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	30+90 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	30+90 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	30+90 d	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	30+90 d	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	30+90 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	30+90 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	30+90 d	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	30+90 d	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	35+105 d	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	35+105 d	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	35+105 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	35+105 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	35+105 d	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
35+105 d	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
35+105 d	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25	
35+105 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
WINTER RYE	35+105 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	35+105 d	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	35+105 d	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	35+105 d	3	2	0	0	0	0	0	0	0	0	0	0	0	0	25	25	25
	35+105 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	35+105 d	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	35+105 d	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	40+120 d	1	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	40+120 d	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	40+120 d	1	3	25	25	25	25	25	25	0	0	0	0	0	0	25	25	50
	40+120 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	40+120 d	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	40+120 d	2	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	40+120 d	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	40+120 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	40+120 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	40+120 d	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	40+120 d	3	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	40+120 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	40+120 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	40+120 d	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	40+120 d	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	45+135 d	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	45+135 d	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25
	45+135 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	45+135 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	45+135 d	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	45+135 d	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	45+135 d	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	45+135 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	50	50
	45+135 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	45+135 d	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
45+135 d	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
45+135 d	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
45+135 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50	
45+135 d	3	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
45+135 d	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	
SPRING RYE	90 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	
	90 days	1	2	0	0	0	0	0	0	0	0	0	0	25	25	25	25	
	90 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	
	90 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	
	90 days	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	
	90 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	
	90 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	
	90 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	
	90 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	
	90 days	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SPRING RYE	90 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	90 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	90 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	25	25	50
	90 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	90 days	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	105 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	105 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	105 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	105 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	105 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	105 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	105 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	105 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	25	25	50
	105 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	105 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	120 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	120 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	120 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	120 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	25	25	50
	120 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	120 days	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	135 days	1	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
	135 days	1	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	135 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	135 days	2	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25
135 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50	
135 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
135 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SPRING RYE	135 days	3	1	100	100	100	50	25	25	25	0	0	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	25
	135 days	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	25	50
	135 days	3	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	135 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
PEARL MILLET	70 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	70 days	1	2	0	0	0	0	0	0	0	25	25	50	50	50	50	50	50
	70 days	1	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	70 days	1	4	0	0	0	0	0	0	0	0	25	25	25	50	50	50	50
	70 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	70 days	2	2	25	25	25	25	0	0	0	25	25	50	50	50	50	50	50
	70 days	2	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	70 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	70 days	3	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	70 days	3	2	25	25	25	25	0	0	0	25	25	50	50	50	50	50	50
	70 days	3	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	70 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	90 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	90 days	1	2	25	25	25	25	0	0	0	25	25	50	50	50	50	50	50
	90 days	1	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	90 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	90 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	90 days	2	2	25	25	25	25	0	0	0	25	25	50	50	50	50	50	50
	90 days	2	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50
	90 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
90 days	3	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0	
90 days	3	2	25	25	25	25	0	0	0	25	25	50	50	50	50	50	50	
90 days	3	3	25	25	25	25	0	0	0	0	25	50	50	50	50	50	50	
90 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
FOXTAIL MILLET	75 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	75 days	1	2	25	25	25	25	25	0	0	0	0	25	50	50	50	50	50
	75 days	1	3	50	50	50	25	0	0	0	0	0	25	25	50	50	50	50
	75 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	75 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	75 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	75 days	2	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	75 days	2	3	50	50	50	25	25	0	0	0	0	0	25	50	50	50	50
	75 days	2	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	75 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	75 days	3	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	75 days	3	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	75 days	3	3	50	50	50	25	25	0	0	0	0	0	25	50	50	50	50
	75 days	3	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
75 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
FOXTAIL MILLET	90 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	90 days	1	2	25	25	25	25	25	0	0	0	0	25	50	50	50	50	50
	90 days	1	3	50	50	50	25	0	0	0	0	0	25	25	50	50	50	50
	90 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	90 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	90 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	90 days	2	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	90 days	2	3	50	50	50	25	25	0	0	0	0	0	25	50	50	50	50
	90 days	2	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	90 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	90 days	3	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	90 days	3	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	90 days	3	3	50	50	50	25	25	0	0	0	0	0	25	50	50	50	50
	90 days	3	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	90 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	105 days	1	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	1	2	25	25	25	25	25	0	0	0	0	25	50	50	50	50	50
	105 days	1	3	50	50	50	25	0	0	0	0	0	25	25	50	50	50	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	105 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	105 days	2	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	105 days	2	3	50	50	50	50	25	0	0	0	0	0	25	50	50	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	105 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	105 days	3	1	100	100	100	50	25	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	105 days	3	3	50	50	50	25	0	0	0	0	0	0	25	50	50	50	50
	105 days	3	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	105 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	25	25	25	25	25	0	0	0	0	25	50	50	50	50	50
	120 days	1	3	50	50	50	25	0	0	0	0	0	25	25	50	50	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	120 days	1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	120 days	2	3	50	50	50	25	0	0	0	0	0	0	25	50	50	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	120 days	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	120 days	3	3	50	50	50	25	0	0	0	0	0	0	25	50	50	50	50
	120 days	3	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	120 days	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Periods														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
WHITE POTATO	90 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	1	2	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	90 days	1	3	25	25	25	25	25	0	0	0	0	25	25	50	50	50	50
	90 days	1	4	0	0	0	0	0	25	0	0	0	25	25	25	50	50	50
	90 days	1	5	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	90 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	2	2	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50
	90 days	2	3	25	25	25	25	25	0	0	0	0	0	25	50	50	50	50
	90 days	2	4	0	0	0	0	0	25	0	0	25	25	50	50	50	50	50
	90 days	2	5	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	90 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	3	2	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50
	90 days	3	3	25	25	25	25	25	0	0	0	0	0	25	50	50	50	50
	90 days	3	4	0	0	0	0	0	25	0	0	25	25	50	50	50	50	50
	90 days	3	5	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	120 days	1	3	25	25	25	25	25	0	0	0	0	25	25	50	50	50	50
	120 days	1	4	0	0	0	0	0	25	0	0	0	25	25	25	50	50	50
	120 days	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50
	120 days	2	3	25	25	25	25	25	0	0	0	0	0	25	50	50	50	50
	120 days	2	4	0	0	0	0	0	25	0	0	25	25	50	50	50	50	50
	120 days	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50
	120 days	3	3	25	25	25	25	25	0	0	0	0	0	25	50	50	50	50
	120 days	3	4	0	0	0	0	0	25	0	0	25	25	50	25	50	50	50
	120 days	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0
	150 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	150 days	1	3	50	50	50	50	25	25	0	0	0	0	25	50	50	50	50
	150 days	1	4	0	0	0	0	0	25	0	0	0	0	25	25	50	50	50
	150 days	1	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0
	150 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	150 days	2	3	50	50	50	50	25	25	0	0	0	0	25	25	50	50	50
	150 days	2	4	0	0	0	0	0	25	0	0	0	25	50	50	50	50	50
	150 days	2	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0
	150 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	150 days	3	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	150 days	3	3	50	50	50	50	25	25	0	0	0	0	25	25	50	50	50
	150 days	3	4	0	0	0	0	0	25	0	0	0	25	50	50	50	50	50
	150 days	3	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
WHITE POTATO	180 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	1	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	180 days	1	3	50	50	50	50	50	25	25	0	0	0	25	50	50	50	50
	180 days	1	4	0	0	0	0	0	25	0	0	0	0	25	25	50	50	50
	180 days	1	5	100	100	100	100	100	100	50	25	0	0	0	0	0	0	0
	180 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	2	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	180 days	2	3	50	50	50	50	50	25	25	0	0	0	25	25	50	50	50
	180 days	2	4	0	0	0	0	0	25	0	0	0	25	50	50	50	50	50
	180 days	2	5	100	100	100	100	100	100	50	25	0	0	0	0	0	0	0
	180 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	3	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	180 days	3	3	50	50	50	50	50	25	25	0	0	0	25	25	50	50	50
	180 days	3	4	0	0	0	0	0	25	0	0	0	25	50	50	50	50	50
	180 days	3	5	100	100	100	100	100	100	50	25	0	0	0	0	0	0	0
CASSAVA	<= 365 d	1	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	<= 365 d	1	2	25	25	0	0	0	0	25	25	25	25	25	25	25	25	25
	<= 365 d	1	3	25	25	25	25	25	25	0	0	0	0	0	25	25	25	25
	<= 365 d	1	4	0	0	0	0	0	25	0	0	0	0	0	0	0	25	25
	<= 365 d	2	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	<= 365 d	2	2	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0
	<= 365 d	2	3	25	25	25	25	25	25	0	0	0	0	0	25	25	25	25
	<= 365 d	2	4	0	0	0	0	0	25	0	0	0	0	0	0	25	50	50
	<= 365 d	3	1	100	100	100	50	50	25	25	0	0	0	0	0	0	0	0
	<= 365 d	3	2	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0
	<= 365 d	3	3	25	25	25	25	25	25	25	0	0	0	0	0	25	25	25
<= 365 d	3	4	0	0	0	0	0	25	0	0	0	0	0	0	25	50	50	
SWEET POTATO	150 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	1	2	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
	150 days	1	3	25	25	25	25	25	0	0	0	0	25	25	50	50	50	50
	150 days	1	4	0	0	0	0	0	25	0	0	0	0	0	0	0	25	50
	150 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	2	2	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
	150 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	150 days	2	4	0	0	0	0	0	25	0	0	0	0	0	0	25	25	50
	150 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	3	2	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
	150 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	150 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	180 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	180 days	1	2	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
	180 days	1	3	25	25	25	25	25	0	0	0	0	25	25	50	50	50	50
	180 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	25	50
	180 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	180 days	2	2	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
	180 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	180 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SWEET POTATO	180 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	180 days	3	2	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
	180 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	180 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	210 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	210 days	1	2	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
	210 days	1	3	25	25	25	25	25	0	0	0	0	25	25	50	50	50	50
	210 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	25	50
	210 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	210 days	2	2	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
	210 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
	210 days	2	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	210 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	210 days	3	2	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
	210 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	25	50	50
210 days	3	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50	
SUGAR-CANE	<= 365 d	1	1	100	100	100	100	50	50	50	25	0	0	0	0	0	0	
	<= 365 d	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	<= 365 d	1	3	0	0	0	0	25	25	0	0	0	0	0	0	0	25	
	<= 365 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	<= 365 d	2	1	100	100	100	100	50	50	50	25	0	0	0	0	0	0	
	<= 365 d	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	<= 365 d	2	3	0	0	0	0	25	25	0	0	0	0	0	0	0	25	
	<= 365 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	<= 365 d	3	1	100	100	100	100	50	50	50	25	0	0	0	0	0	0	
	<= 365 d	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	<= 365 d	3	3	0	0	0	0	25	25	0	0	0	0	0	0	0	25	
<= 365 d	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
SUGAR-BEET	150 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	150 days	1	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	150 days	1	3	25	25	25	25	25	0	0	0	0	0	25	25	50	50	
	150 days	1	4	0	0	0	0	0	25	0	0	0	0	0	25	50	50	
	150 days	1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	
	150 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	
	150 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	
	150 days	2	4	0	0	0	0	0	25	0	0	0	0	0	25	25	50	50
	150 days	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	
	150 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	
	150 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	
	150 days	3	4	0	0	0	0	0	25	0	0	0	25	25	25	50	50	
	150 days	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	
	165 days	1	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	
	165 days	1	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	165 days	1	3	25	25	25	25	25	0	0	0	0	0	25	25	50	50	
	165 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	50	
	165 days	1	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SUGAR-BEET	165 days	2	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	165 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	165 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	50
	165 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	165 days	2	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0
	165 days	3	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	165 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	165 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	50
	165 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	165 days	3	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0
	180 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	1	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	180 days	1	3	25	25	25	25	25	0	0	0	0	0	25	25	50	50	50
	180 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	50	50
	180 days	1	5	100	100	100	100	100	100	50	0	0	0	0	0	0	0	0
	180 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	180 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	50
	180 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	180 days	2	5	100	100	100	100	100	100	50	0	0	0	0	0	0	0	0
	180 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	180 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	50
	180 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	180 days	3	5	100	100	100	100	100	100	50	0	0	0	0	0	0	0	0
	195 days	1	1	100	100	100	50	50	50	50	0	0	0	0	0	0	0	0
	195 days	1	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	195 days	1	3	25	25	25	25	25	0	0	0	0	0	25	25	50	50	50
	195 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	50	50
	195 days	1	5	100	100	100	100	100	100	100	25	0	0	0	0	0	0	0
	195 days	2	1	100	100	100	50	50	50	50	0	0	0	0	0	0	0	0
	195 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	195 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	50
	195 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	195 days	2	5	100	100	100	100	100	100	100	25	0	0	0	0	0	0	0
	195 days	3	1	100	100	100	50	50	50	50	0	0	0	0	0	0	0	0
	195 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	195 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	50
	195 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	195 days	3	5	100	100	100	100	100	100	100	25	0	0	0	0	0	0	0
210 days	1	1	100	100	100	50	50	50	50	0	0	0	0	0	0	0	0	
210 days	1	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
210 days	1	3	25	25	25	25	25	0	0	0	0	0	25	25	50	50	50	
210 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	50	50	
210 days	1	5	100	100	100	100	100	100	100	50	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
SUGAR-BEET	210 days	2	1	100	100	100	50	50	50	50	25	0	0	0	0	0	0	0	
	210 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	210 days	2	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	50	
	210 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50	
	210 days	2	5	100	100	100	100	100	100	100	50	0	0	0	0	0	0	0	
	210 days	3	1	100	100	100	50	50	50	50	25	0	0	0	0	0	0	0	
	210 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	210 days	3	3	25	25	25	25	25	0	0	0	0	0	0	25	50	50	50	
	210 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
	210 days	3	5	100	100	100	100	100	100	100	50	0	0	0	0	0	0	0	
PHASEOL. BEAN, LOWLAND	90 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	90 days	1	2	0	0	0	0	0	0	0	25	25	50	50	50	50	50	50	
	90 days	1	3	50	50	50	50	25	0	0	0	25	25	25	25	50	50	50	
	90 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	90 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	90 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	90 days	2	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50	
	90 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
	90 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	90 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	90 days	3	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50	
	90 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50	
	120 days	1	3	50	50	50	50	25	0	0	0	25	25	25	25	50	50	50	
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	120 days	2	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50	
	120 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	120 days	3	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50	
	120 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
	150 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50	
	150 days	1	3	50	50	50	50	25	0	0	0	25	25	25	25	50	50	50	
	150 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	150 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	150 days	2	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50	
	150 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	
	150 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	0
150 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50		
150 days	3	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50		
150 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50		

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
PHASEOL. BEAN, HIGHLAND	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	25	25	50	50	50	50	50	50
	120 days	1	3	50	50	50	50	25	0	0	0	25	25	25	25	50	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	120 days	2	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	120 days	3	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50
	120 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	150 days	1	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	25	25	50	50	50	50	50	50
	150 days	1	3	50	50	50	50	50	25	0	0	25	25	25	25	50	50	50
	150 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	150 days	2	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	150 days	2	3	100	100	100	50	50	25	0	0	0	0	0	25	50	50	50
	150 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	150 days	3	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	150 days	3	3	50	50	50	50	50	25	0	0	0	0	0	25	50	50	50
	150 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	180 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	1	2	0	0	0	0	0	0	0	25	25	50	50	50	50	50	50
	180 days	1	3	50	50	50	50	50	50	25	0	25	25	25	25	50	50	50
	180 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	180 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
180 days	2	3	50	50	50	50	50	50	25	0	0	0	0	25	50	50	50	
180 days	2	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
180 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
180 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
180 days	3	3	50	50	50	50	50	50	25	0	0	0	0	25	50	50	50	
180 days	3	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
PHASEOL. BEAN, TEMPER.	90 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	90 days	1	2	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	90 days	1	3	50	50	50	50	25	0	0	0	0	25	25	25	25	50	50
	90 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	90 days	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	90 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	90 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	50	50
	90 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	90 days	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
PHASEOL. BEAN, TEMPER.	90 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	90 days	3	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50
	90 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	90 days	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	120 days	1	3	50	50	50	50	25	0	0	0	0	25	25	25	25	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	120 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	2	3	50	50	50	50	25	0	0	0	0	0	0	0	25	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	120 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	3	3	50	50	50	50	25	0	0	0	0	0	0	0	25	50	50
	120 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	120 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	150 days	1	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	150 days	1	3	50	50	50	50	50	25	0	0	0	25	25	25	25	50	50
	150 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50
	150 days	1	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0
	150 days	2	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	150 days	2	3	50	50	50	50	50	25	0	0	0	0	0	0	25	50	50
	150 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	150 days	2	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0
150 days	3	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0	
150 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50	
150 days	3	3	50	50	50	50	50	25	0	0	0	0	0	0	25	50	50	
150 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
150 days	3	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0	
CHICKPEA	90 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	
	90 days	1	2	25	25	25	25	0	0	0	0	0	25	50	50	50	50	50
	90 days	1	3	50	50	50	25	25	25	0	0	0	25	50	50	50	50	50
	90 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	90 days	1	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0
	90 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	90 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	90 days	2	3	25	25	25	25	25	0	0	0	0	0	25	50	50	50	50
	90 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
90 days	2	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
CHICKPEA	90 days	3	1	100	100	100	25	25	0	0	0	0	0	0	0	0	0	0	
	90 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	90 days	3	3	25	25	25	25	0	0	0	0	0	0	0	50	50	50	50	
	90 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	90 days	3	5	100	100	100	100	25	0	0	0	0	0	0	0	0	0	0	
	105 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0	
	105 days	1	2	25	25	25	25	0	0	0	0	0	25	50	50	50	50	50	
	105 days	1	3	50	50	50	25	25	25	0	0	0	25	50	50	50	50	50	
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	105 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0	
	105 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0	
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	105 days	2	3	25	25	25	25	25	0	0	0	0	0	25	50	50	50	50	
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	105 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0	
	105 days	3	1	100	100	100	25	25	0	0	0	0	0	0	0	0	0	0	
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	105 days	3	3	25	25	25	25	0	0	0	0	0	0	0	50	50	50	50	
	105 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	105 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0	
	120 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0	
	120 days	1	2	25	25	25	25	0	0	0	0	0	25	50	50	50	50	50	
	120 days	1	3	50	50	50	25	25	25	0	0	0	25	50	50	50	50	50	
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	120 days	1	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0	
	120 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0	
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	120 days	2	3	25	25	25	25	25	0	0	0	0	0	25	50	50	50	50	
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	120 days	2	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0	
	120 days	3	1	100	100	100	25	25	0	0	0	0	0	0	0	0	0	0	
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	120 days	3	3	25	25	25	25	0	0	0	0	0	0	0	50	50	50	50	
	120 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	120 days	3	5	100	100	100	100	50	25	0	0	0	0	0	0	0	0	0	
	CHICKPEA (CR)	150 days	1	1	100	100	100	100	50	0	0	0	0	0	0	0	0	0	
150 days		1	2	25	25	25	25	0	0	0	0	0	25	50	50	50	50		
150 days		1	3	50	50	50	25	25	25	0	0	0	25	50	50	50	50		
150 days		1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50		
150 days		1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0		
150 days		2	1	100	100	100	100	50	0	0	0	0	0	0	0	0	0		
150 days		2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50		
150 days		2	3	25	25	25	25	25	0	0	0	0	0	25	50	50	50		
150 days		2	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50		
150 days	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0			

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
CHICKPEA (CR)	150 days	3	1	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	150 days	3	3	25	25	25	25	0	0	0	0	0	0	0	50	50	50	50
	150 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	150 days	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	180 days	1	1	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	180 days	1	2	25	25	25	25	25	0	0	0	0	25	50	50	50	50	50
	180 days	1	3	50	50	50	25	25	25	0	0	0	25	50	50	50	50	50
	180 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	180 days	1	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0
	180 days	2	1	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	180 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	180 days	2	3	25	25	25	25	25	0	0	0	0	0	25	50	50	50	50
	180 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50
	180 days	2	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0
	180 days	3	1	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0
	180 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	180 days	3	3	25	25	25	25	0	0	0	0	0	0	0	50	50	50	50
	180 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	180 days	3	5	100	100	100	100	100	50	25	0	0	0	0	0	0	0	0
COWPEA	80 days	1	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	80 days	1	2	25	25	0	0	0	0	0	0	25	25	25	25	25	50	50
	80 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	25	50	50
	80 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	80 days	2	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	80 days	2	2	25	25	0	0	0	0	0	0	0	25	25	25	25	25	50
	80 days	2	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	80 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	80 days	3	1	100	100	100	50	25	0	0	0	0	0	0	0	0	0	0
	80 days	3	2	25	25	0	0	0	0	0	0	0	0	0	25	25	25	50
	80 days	3	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	80 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	100 days	1	1	100	100	100	50	50	0	0	0	0	0	0	0	0	0	0
	100 days	1	2	25	25	0	0	0	0	0	0	0	25	25	25	25	50	50
	100 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	25	50	50
	100 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50
	100 days	2	1	100	100	100	50	50	0	0	0	0	0	0	0	0	0	0
	100 days	2	2	25	25	0	0	0	0	0	0	0	25	25	25	25	25	50
	100 days	2	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	100 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	100 days	3	1	100	100	100	50	50	0	0	0	0	0	0	0	0	0	0
	100 days	3	2	25	25	0	0	0	0	0	0	0	0	0	25	25	25	50
	100 days	3	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	100 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	25	25	0	0	0	0	0	0	0	25	25	25	25	50	50
	120 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	25	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	0	25	25	50

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
COWPEA	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	25	25	0	0	0	0	0	0	0	25	25	25	25	25	50
	120 days	2	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	25	25	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	3	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	120 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
GROUND-NUT	90 days	1	1	100	100	100	50	50	0	0	0	0	0	0	0	0	0	0
	90 days	1	2	0	0	0	0	0	0	0	0	25	25	25	25	50	50	50
	90 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	25	50	50
	90 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	90 days	2	1	100	100	100	50	50	0	0	0	0	0	0	0	0	0	0
	90 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	50	50
	90 days	2	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	90 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	90 days	3	1	100	100	100	50	50	0	0	0	0	0	0	0	0	0	0
	90 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	90 days	3	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	90 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	105 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	50	50
	105 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	25	50	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	105 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	50	50
	105 days	2	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	105 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	105 days	3	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	105 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	25	50	50
	120 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	25	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	25	50
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	25	50	50
	120 days	2	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	0	0	25	25	25	25	50
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	25	25	50
	120 days	3	3	50	50	50	50	25	25	0	0	0	0	0	0	25	50	50
	120 days	3	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SOYBEAN, TROPICS	90 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	1	2	0	0	0	0	0	0	0	25	25	25	25	50	50	50	50
	90 days	1	3	50	50	50	50	25	0	0	0	25	25	25	25	50	50	50
	90 days	1	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	90 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	90 days	2	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50
	90 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	90 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	90 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	90 days	3	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50
	90 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	105 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	1	2	0	0	0	0	0	0	0	25	25	25	25	50	50	50	50
	105 days	1	3	50	50	50	50	25	0	0	0	25	25	25	25	50	50	50
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	105 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	105 days	2	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	105 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	105 days	3	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50
	105 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	1	2	0	0	0	0	0	0	0	25	25	25	25	50	50	50	50
	120 days	1	3	50	50	50	50	25	0	0	0	25	25	25	25	50	50	50
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	120 days	2	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50
	120 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	120 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	120 days	3	3	50	50	50	50	25	0	0	0	0	0	0	25	50	50	50
	120 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
SOYBEAN, SUB-TROPICS	105 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	105 days	1	2	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
	105 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	50	50	
	105 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50	
	105 days	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	
	105 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	105 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50
	105 days	2	3	50	50	50	50	25	25	0	0	0	0	0	25	25	50	50
	105 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	105 days	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
SOYBEAN, SUB-TROPICS	105 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	105 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	105 days	3	3	50	50	50	50	25	25	0	0	0	0	0	25	25	50	50	
	105 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	105 days	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0	
	120 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	120 days	1	2	0	0	0	0	0	0	0	0	25	25	25	50	50	50	50	
	120 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	50	50	50	
	120 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50	
	120 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	
	120 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	120 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	120 days	2	3	50	50	50	50	25	25	0	0	0	0	0	25	25	50	50	
	120 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	120 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	
	120 days	3	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0	
	120 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	120 days	3	3	50	50	50	50	25	25	0	0	0	0	0	25	25	50	50	
	120 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	120 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0	
	135 days	1	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0	
	135 days	1	2	0	0	0	0	0	0	0	0	25	25	25	50	50	50	50	
	135 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	50	50	50	
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	0	25	25	50	50	
	135 days	1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	
	135 days	2	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0	
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	135 days	2	3	50	50	50	50	25	25	0	0	0	0	0	25	25	50	50	
	135 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	135 days	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	
	135 days	3	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0	
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	135 days	3	3	50	50	50	50	25	25	0	0	0	0	0	25	25	50	50	
	135 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	135 days	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	
	SUN-FLOWER, TROPICS	135 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
135 days		1	2	25	25	25	25	25	0	0	0	25	25	50	50	50	50	50	
135 days		1	3	50	50	50	50	25	0	0	0	25	50	50	50	50	50	50	
135 days		1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
135 days		2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
135 days		2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
135 days		2	3	50	50	50	50	25	0	0	0	25	25	50	50	50	50	50	
135 days		2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50	
135 days		3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
135 days		3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
135 days		3	3	50	50	50	50	25	0	0	0	25	25	50	50	50	50	50	
135 days		3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
SUN- FLOWER, TROPICS	150 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	1	2	25	25	25	25	25	0	0	0	25	25	50	50	50	50	50
	150 days	1	3	50	50	50	50	25	0	0	0	25	50	50	50	50	50	50
	150 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	150 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	150 days	2	3	50	50	50	50	25	0	0	0	25	25	50	50	50	50	50
	150 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	150 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	150 days	3	3	50	50	50	50	25	0	0	0	25	25	50	50	50	50	50
	150 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	165 days	1	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	165 days	1	2	25	25	25	25	25	0	0	0	25	25	50	50	50	50	50
	165 days	1	3	50	50	50	50	25	0	0	0	25	50	50	50	50	50	50
	165 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	165 days	2	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	165 days	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	165 days	2	3	50	50	50	50	25	0	0	0	25	25	50	50	50	50	50
	165 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
165 days	3	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0	
165 days	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
165 days	3	3	50	50	50	50	25	0	0	0	25	25	50	50	50	50	50	
165 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50	
SUN- FLOWER, SUB- TROPICS	135 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	1	2	25	25	25	25	25	0	0	0	25	25	50	50	50	50	50
	135 days	1	3	50	50	50	50	25	0	0	0	0	25	50	50	50	50	50
	135 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	135 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	135 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	135 days	2	3	50	50	50	50	25	0	0	0	0	0	25	50	50	50	50
	135 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	135 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	135 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50
	135 days	3	3	50	50	50	50	25	0	0	0	0	0	25	50	50	50	50
	135 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	135 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	150 days	1	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0
	150 days	1	2	25	25	25	25	25	0	0	0	25	25	50	50	50	50	50
	150 days	1	3	50	50	50	50	25	0	0	0	0	25	50	50	50	50	50
	150 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	150 days	1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
150 days	2	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0	0	
150 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50	50	
150 days	2	3	50	50	50	50	25	0	0	0	0	0	25	50	50	50	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
SUN- FLOWER, SUB- TROPICS	150 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50		
	150 days	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0		
	150 days	3	1	100	100	100	50	50	50	0	0	0	0	0	0	0	0		
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50		
	150 days	3	3	50	50	50	50	25	0	0	0	0	0	25	50	50	50		
	150 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50		
	150 days	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0		
	165 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0		
	165 days	1	2	25	25	25	25	25	0	0	0	25	25	50	50	50	50		
	165 days	1	3	50	50	50	50	25	0	0	0	0	25	50	50	50	50		
	165 days	1	4	0	0	0	0	0	0	0	0	0	25	25	25	50	50		
	165 days	1	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0		
	165 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0		
	165 days	2	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50		
	165 days	2	3	50	50	50	50	25	0	0	0	0	0	25	50	50	50		
	165 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50		
	165 days	2	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0		
	165 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0		
	165 days	3	2	0	0	0	0	0	0	0	0	0	0	0	25	50	50		
	165 days	3	3	50	50	50	50	25	0	0	0	0	0	25	50	50	50		
165 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50			
165 days	3	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0			
WINTER RAPE	35+105 d	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0		
	35+105 d	1	2	0	0	0	0	0	0	0	0	25	25	25	50	50	50		
	35+105 d	1	3	50	50	50	50	25	25	0	0	0	0	25	50	50	50		
	35+105 d	1	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50		
	35+105 d	1	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0		
	35+105 d	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0		
	35+105 d	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50		
	35+105 d	2	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50		
	35+105 d	2	4	0	0	0	0	0	0	0	0	25	25	25	50	50	50		
	35+105 d	2	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0		
	35+105 d	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0		
	35+105 d	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50		
	35+105 d	3	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50		
	35+105 d	3	4	0	0	0	0	0	0	0	0	25	25	25	50	50	50		
	35+105 d	3	5	100	100	100	100	50	0	0	0	0	0	0	0	0	0		
	45+120 d	1	1	100	100	100	100	50	50	25	0	0	0	0	0	0	0		
	45+120 d	1	2	0	0	0	0	0	0	0	0	25	25	25	50	50	50		
	45+120 d	1	3	50	50	50	50	25	25	0	0	0	0	25	50	50	50		
	45+120 d	1	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50		
	45+120 d	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0		
45+120 d	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0			
45+120 d	2	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50			
45+120 d	2	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50			
45+120 d	2	4	0	0	0	0	0	0	0	0	25	25	25	50	50	50			
45+120 d	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0			

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
WINTER RAPE	45+120 d	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	45+120 d	3	2	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50
	45+120 d	3	3	50	50	50	50	25	25	0	0	0	0	25	50	50	50	50
	45+120 d	3	4	0	0	0	0	0	0	0	25	25	25	50	50	50	50	50
	45+120 d	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
SPRING RAPE	135 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	135 days	1	2	0	0	0	0	0	0	0	25	25	25	50	50	50	50	50
	135 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	50	50	50
	135 days	1	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50
	135 days	1	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	135 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	135 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	135 days	2	3	50	50	50	50	25	25	0	0	0	0	25	50	50	50	50
	135 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	135 days	2	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	135 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	135 days	3	3	50	50	50	50	25	25	0	0	0	0	25	50	50	50	50
	135 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	135 days	3	5	100	100	100	100	100	25	0	0	0	0	0	0	0	0	0
	150 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	25	25	25	50	50	50	50	50
	150 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	50	50	50
	150 days	1	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50
	150 days	1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	150 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	150 days	2	3	50	50	50	50	25	25	0	0	0	0	25	50	50	50	50
	150 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	150 days	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	150 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	150 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	150 days	3	3	50	50	50	50	25	25	0	0	0	0	25	50	50	50	50
	150 days	3	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	150 days	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0
	165 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	165 days	1	2	0	0	0	0	0	0	0	25	25	25	50	50	50	50	50
	165 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	50	50	50
	165 days	1	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50
	165 days	1	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0
	165 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	165 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50
	165 days	2	3	50	50	50	50	25	25	0	0	0	0	25	50	50	50	50
	165 days	2	4	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50
	165 days	2	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0
165 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
165 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
SPRING RAPE	165 days	3	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50	50	
	165 days	3	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	165 days	3	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0	
RAPE, SUB-TROP./TROPICS	135 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	135 days	1	2	0	0	0	0	0	0	0	0	25	25	25	50	50	50	50	
	135 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	50	50	50	
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	135 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	135 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	135 days	2	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50	50	
	135 days	2	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	135 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	135 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	135 days	3	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50	50	
	135 days	3	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	150 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
	150 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	50	50	50	
	150 days	1	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	150 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	150 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	150 days	2	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50	50	
	150 days	2	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	150 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	150 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	150 days	3	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50	50	
	150 days	3	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	165 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	165 days	1	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
	165 days	1	3	50	50	50	50	25	25	0	0	0	25	25	25	50	50	50	
	165 days	1	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
	165 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	165 days	2	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	
	165 days	2	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50	50	
	165 days	2	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	165 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
165 days	3	2	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50		
165 days	3	3	50	50	50	50	25	25	0	0	0	0	0	25	50	50	50		
165 days	3	4	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50		
COTTON, TROPICS	135 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0		
	135 days	1	2	0	0	0	0	25	25	25	25	25	25	25	50	50	50		
	135 days	1	3	0	0	0	0	25	25	25	25	25	25	50	50	50	50		
	135 days	1	4	0	0	0	0	0	0	0	0	0	0	25	25	50	50		
	135 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0		
	135 days	2	2	0	0	0	0	0	0	0	0	25	25	25	25	50	50		
	135 days	2	3	0	0	0	0	0	0	0	0	25	25	50	50	50	50		
	135 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50		

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
COTTON, TROPICS	135 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	135 days	3	2	0	0	0	0	0	0	0	0	25	25	25	25	50	50	50
	135 days	3	3	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	135 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	150 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	1	2	0	0	0	0	25	25	25	25	25	25	25	50	50	50	50
	150 days	1	3	0	0	0	0	25	25	25	25	25	25	50	50	50	50	50
	150 days	1	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	150 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	150 days	2	2	0	0	0	0	0	0	0	0	25	25	25	25	50	50	50
	150 days	2	3	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	150 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	150 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	150 days	3	2	0	0	0	0	0	0	0	0	25	25	25	25	50	50	50
	150 days	3	3	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	150 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	165 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	165 days	1	2	0	0	0	0	25	25	25	25	25	25	25	50	50	50	50
	165 days	1	3	0	0	0	0	25	25	25	25	25	25	25	50	50	50	50
	165 days	1	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	165 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	165 days	2	2	0	0	0	0	0	0	0	0	25	25	25	25	50	50	50
	165 days	2	3	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	165 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	165 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	165 days	3	2	0	0	0	0	0	0	0	0	25	25	25	25	50	50	50
	165 days	3	3	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	165 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	180 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	1	2	0	0	0	0	25	25	25	25	25	25	25	50	50	50	50
	180 days	1	3	0	0	0	0	25	25	25	25	25	25	25	50	50	50	50
	180 days	1	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50
	180 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	2	2	0	0	0	0	0	0	0	0	25	25	25	25	50	50	50
	180 days	2	3	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	180 days	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	180 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0
	180 days	3	2	0	0	0	0	0	0	0	0	25	25	25	25	50	50	50
	180 days	3	3	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
	180 days	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50
COTTON, SUB-TROPICS	135 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	135 days	1	2	0	0	0	0	25	25	25	25	25	25	25	50	50	50	
	135 days	1	3	0	0	0	0	25	25	25	25	25	25	50	50	50	50	
	135 days	1	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	135 days	1	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	
	135 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	
	135 days	2	2	0	0	0	0	0	0	0	0	25	25	25	50	50	50	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
COTTON, SUB-TROPICS	135 days	2	3	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	135 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	135 days	2	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0	
	135 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	135 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
	135 days	3	3	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	135 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	135 days	3	5	100	100	100	100	100	100	25	0	0	0	0	0	0	0	0	
	150 days	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	150 days	1	2	0	0	0	0	25	25	25	25	25	25	25	50	50	50	50	
	150 days	1	3	0	0	0	0	25	25	25	25	25	25	50	50	50	50	50	
	150 days	1	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	150 days	1	5	100	100	100	100	100	100	50	0	0	0	0	0	0	0	0	
	150 days	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	150 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
	150 days	2	3	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	150 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	150 days	2	5	100	100	100	100	100	100	50	0	0	0	0	0	0	0	0	
	150 days	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	150 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
	150 days	3	3	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	
	150 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	150 days	3	5	100	100	100	100	100	100	50	0	0	0	0	0	0	0	0	
	165 days	1	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	165 days	1	2	0	0	0	0	25	25	25	25	25	25	25	50	50	50	50	
	165 days	1	3	0	0	0	0	25	25	25	25	25	25	50	50	50	50	50	
	165 days	1	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	165 days	1	5	100	100	100	100	100	100	50	25	0	0	0	0	0	0	0	
	165 days	2	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0	
	165 days	2	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50	
165 days	2	3	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50		
165 days	2	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50		
165 days	2	5	100	100	100	100	100	100	50	25	0	0	0	0	0	0	0		
165 days	3	1	100	100	100	50	50	50	25	0	0	0	0	0	0	0	0		
165 days	3	2	0	0	0	0	0	0	0	0	0	25	25	25	50	50	50		
165 days	3	3	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50		
165 days	3	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50		
165 days	3	5	100	100	100	100	100	100	100	25	0	0	0	0	0	0	0		
BANANA/ PLANTAIN	<= 365 d	1	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0		
	<= 365 d	1	2	50	50	50	50	50	25	25	25	0	0	25	25	50	50	50	
	<= 365 d	1	3	50	50	50	50	50	50	50	50	25	25	0	0	0	25	25	
	<= 365 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	<= 365 d	2	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0	
	<= 365 d	2	2	50	50	50	50	50	25	25	25	0	0	0	0	25	25	25	
	<= 365 d	2	3	50	50	50	50	50	50	50	50	25	25	0	0	0	25	25	
	<= 365 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period															
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+	
BANANA/ PLANTAIN	<= 365 d	3	1	100	100	100	50	50	50	50	25	25	0	0	0	0	0	0	
	<= 365 d	3	2	50	50	50	50	50	25	25	25	0	0	0	0	0	0	0	
	<= 365 d	3	3	50	50	50	50	50	50	50	25	25	0	0	0	0	0	25	
	<= 365 d	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
OILPALM	<= 365 d	1	1	100	100	100	50	50	50	50	25	25	25	0	0	0	0	0	
	<= 365 d	1	2	50	50	50	50	50	25	25	25	0	0	0	0	0	0	0	
	<= 365 d	1	3	50	50	50	50	50	50	50	50	50	50	0	0	25	25	25	
	<= 365 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	<= 365 d	2	1	100	100	100	50	50	50	50	25	25	25	0	0	0	0	0	
	<= 365 d	2	2	50	50	50	50	50	25	25	25	0	0	0	0	0	0	0	
	<= 365 d	2	3	50	50	50	50	50	50	50	50	50	50	0	0	0	0	25	
	<= 365 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	<= 365 d	3	1	100	100	100	50	50	50	50	25	25	25	0	0	0	0	0	
	<= 365 d	3	2	50	50	50	50	50	25	25	25	0	0	0	0	0	0	0	
	<= 365 d	3	3	50	50	50	50	50	50	50	50	50	50	0	0	0	0	0	
	<= 365 d	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	OLIVE	<= 365 d	1	1	100	100	50	25	25	0	0	0	0	0	0	0	0	0	0
		<= 365 d	1	2	0	0	0	0	0	0	0	25	25	50	50	50	50	50	50
<= 365 d		1	3	25	25	25	25	0	0	0	0	25	25	50	50	50	50	50	
<= 365 d		1	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
<= 365 d		1	5	100	100	100	100	100	100	100	50	0	0	0	0	0	0	0	
<= 365 d		2	1	100	100	100	25	25	0	0	0	0	0	0	0	0	0	0	
<= 365 d		2	2	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50	
<= 365 d		2	3	25	25	25	25	0	0	0	0	0	25	25	50	50	50	50	
<= 365 d		2	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
<= 365 d		2	5	100	100	100	100	100	100	100	50	0	0	0	0	0	0	0	
<= 365 d		3	1	100	100	100	25	25	0	0	0	0	0	0	0	0	0	0	
<= 365 d		3	2	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50	
<= 365 d		3	3	25	25	25	25	0	0	0	0	0	25	25	50	50	50	50	
<= 365 d		3	4	0	0	0	0	0	0	0	0	0	0	25	50	50	50	50	
<= 365 d		3	5	100	100	100	100	100	100	100	50	0	0	0	0	0	0	0	
ALFALFA		<= 365 d	1	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0
	<= 365 d	1	2	25	25	25	25	0	0	0	0	0	25	25	50	50	50	50	
	<= 365 d	1	3	25	25	25	25	0	0	0	0	0	0	0	25	50	50	50	
	<= 365 d	1	4	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	<= 365 d	1	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	
	<= 365 d	2	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	<= 365 d	2	2	0	0	0	0	0	0	0	0	0	25	25	50	50	50	50	
	<= 365 d	2	3	25	25	25	25	25	0	0	0	0	0	0	0	25	50	50	
	<= 365 d	2	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50	
	<= 365 d	2	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	
	<= 365 d	3	1	100	100	100	50	50	25	0	0	0	0	0	0	0	0	0	
	<= 365 d	3	2	0	0	0	0	0	0	0	0	0	0	25	25	50	50	50	
	<= 365 d	3	3	25	25	25	25	25	0	0	0	0	0	0	0	25	50	50	
	<= 365 d	3	4	0	0	0	0	0	0	0	0	25	25	50	50	50	50	50	
	<= 365 d	3	5	100	100	100	100	100	50	0	0	0	0	0	0	0	0	0	

Crop	Growth cycle	Input levels	Con-straint	Length of Growing Period														
				0	15	45	75	105	135	165	195	225	255	285	315	345	365-	365+
PASTURE	<= 365 d	1	1	100	100	50	50	25	25	25	25	0	0	0	0	0	0	0
	<= 365 d	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<= 365 d	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<= 365 d	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	<= 365 d	2	1	100	100	50	50	25	25	25	25	0	0	0	0	0	0	0
	<= 365 d	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<= 365 d	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<= 365 d	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
	<= 365 d	3	1	100	100	50	50	25	25	25	25	0	0	0	0	0	0	0
	<= 365 d	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<= 365 d	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<= 365 d	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25

APPENDIX IX

CROP SUITABILITY OF WATER COLLECTING SITES

Short-term dryland crops I

This group includes some short duration crops (wheat, barley, rye, dryland rice, foxtail millet, chickpea, rape, and forage legumes which are somewhat tolerant to excess moisture. For LGPs less than 30 days it is assumed there is on the average insufficient water to bring these crops to maturation and yield, especially since the contribution from rainfall is also almost non-existent. At LGPs longer than 120 days these crops will grow irrespective additional water. It has been assumed that the Fluvisols are too wet in LGPs over 300 days. Most of these crops are marginal to not suitable in humid areas. Agro-climatic constraints alone will render these long LGPs already marginal to not suitable.

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS						33	33	33	33	33	33				
S					33										
MS				33		33	33	33	33	33	33				
mS			33		33										
NS	100	100	67	67	34	34	34	34	34	34	34	100	100	100	100

Short-term dryland crops II

The crops in this group (sorghum, pearl millet, cowpea) have either a shorter duration than Group I (pearl millet and cowpea) or tolerance to both drought as well as to excess water (sorghum). Therefore for some parts of the Fluvisols in 1-29 days growing periods some modest yield may be expected (though not in all years). At the wet end of the LGPs these crops are treated similarly to Group I.

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS					33	33	33	33	33	33	33				
S				33											
MS			33		33	33	33	33	33	33	33				
mS		33		33											
NS	100	67	67	34	34	34	34	34	34	34	34	100	100	100	100

Short-term dryland crops III

The crops in Group III include maize, phaseolus bean, soybean, and sunflower. They are more sensitive to excess water (especially water-logging) than Group I and II crops. Therefore, they are not considered to be suitable in areas where LGP exceeds 270 days. Their water requirements are similar or somewhat higher than Group I crops.

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS						33	33	33	33						
S					33										
MS				33		33	33	33	33	33					
mS			33		33										
NS	100	100	67	67	34	34	34	34	34	67	100	100	100	100	100

Short-term dryland crops IV

Root crops (white potato, sweet potato, sugarbeet) are all sensitive to high groundwater levels and water-logging. Cotton and groundnut are also very sensitive to excess moisture. These crops can only be grown on the rarely flooded parts of the Fluvisols, provided they are well drained. Apart from groundnut the growth cycles of the crops in this group are slightly longer than the crops in Group I-III. This makes crops in Group IV slightly more vulnerable.

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS															
S															
MS						33	33	33	33						
mS					33	33	33	33	33	33					
NS	100	100	100	100	67	34	34	34	34	67	100	100	100	100	100

Wetland rice

Wetland Rice is difficult to grow under rainfed conditions. In particular the water management is problematic. Yields obtained from purely rainfed paddy is generally low. 2-3 t/ha is already good. Flood water supply comes in the semiarid areas in an erratic fashion; too little too late or too much too soon. In the sub-humid and humid areas the flood hazard makes management difficult (submerging and flood damage by flowing water). LGPs less than 150 days have been considered insufficient to obtain yield. Very long LGPs are assumed to be associated with high flood risks (submerging, flowing water, high water levels during maturing and harvest).

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS															
S							33	33	33						
MS							33			33	33	33			
mS						33								33	
NS	100	100	100	100	100	67	67	67	67	67	67	67	67	67	100

Cassava

Cassava is preferably *not grown* on Fluvisols because of its sensitivity for excessive wetness in the soil. On the higher parts of Fluvisols short duration cassava can be found (e.g., LGP of 180-270 days in Ghana). Since cassava is not really benefiting from extra moisture, the best

LGPs are those where also rainfed cassava would do reasonably well. Towards the wetter end of the LGPs (more than 240-270 days) cassava is not anymore to be considered on Fluvisols.

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS															
S															
MS								33	33						
mS							33			33					
NS	100	100	100	100	100	100	67	67	67	67	100	100	100	100	100

Sugarcane

Sugarcane is fairly tolerant to flooding and water-logging (e.g., see FAO, 1988). The water from rainfall and whatever comes from the Fluvisols must meet full crop water requirements for 8 to 9 months. It is assumed that the contribution through additional water from Fluvisols sufficiently extends the growing period starting from LGP 180- 210 days onwards. At harvest presence of excess moisture is less favorable for both yield and management of the crop. There need be a predictable period during which the Fluvisol environment provides at least 2 months of dryer conditions.

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS															
S										33	33				
MS									33			33			
mS								33							
NS	100	100	100	100	100	100	100	67	67	67	67	67	100	100	100

Banana/plantain, oil palm

Banana/plantain and oil palm prefer humid conditions. Banana is somewhat tolerant to water-logging, oil palm somewhat less. High groundwater tables are not tolerated. Both perennials require at least eight months during which full water requirements are met. Fluvisols occurring in LGPs of more than 300 days are assumed to be associated with longer periods with high groundwater levels and are therefore unsuited for oil palm and banana/plantain.

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS															
S															
MS								33	33	33					
mS							33				33				
NS	100	100	100	100	100	100	67	67	67	67	67	100	100	100	100

Olives

Olives tolerate neither high groundwater tables nor water-logging and flooding or inundation. Therefore, olives are not considered for cultivation on Fluvisols.

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS															
S															
MS															
mS															
NS	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Pastures

Natural pastures are well adapted to wet conditions. Normally the species mix is fine-tuned to the environmental conditions. Artificial (sown) pastures might grow unevenly on Fluvisols depending on both local differences of soil fertility and water supply. The total period of water availability on Fluvisols can be considered an adequate measure of the productivity regarding pastures (of course, periods of water-logging, flooding and inundation are to be subtracted).

Suit-ability class	Percentage of water-collecting sites suitable per LGP class														
	0	1-29	30-59	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365-	365+
VS						33	33	33	67	67	67	33			
S				33	33		33	33	33	33	33		33		
MS			33		33	33		34				33		33	
mS		33		33			34						33	33	33
NS	100	67	67	34	34	34						34	34	34	67

APPENDIX X

FAO '74 SOIL UNIT RATINGS FOR RAINFED CONDITIONS (at HIGH INPUT LEVEL)

Soil		Crops																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
G	001	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	6	4	4	4	4	1
Ge	002	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	6	4	4	4	4	1
Gc	003	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	4	4	4	4	4	1
Gd	004	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	6	4	4	4	4	1
Gm	005	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	6	4	4	4	4	1
Gh	006	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	6	4	4	4	4	1
Gp	007	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
Gx	008	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
R	009	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Re	010	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rc	011	1	3	3	3	1	1	1	1	1	2	6	3	1	3	3	3	2	1	3	2	1	1	2	6	1	3	1	
Rd	012	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rx	013	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
I	014	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
Q	015	6	4	4	2	2	2	6	1	2	3	2	6	6	2	2	2	2	1	2	2	6	6	6	2	3	2	6	
Qc	016	6	4	4	2	2	2	6	1	2	3	2	6	6	2	2	2	2	1	2	2	6	6	6	2	3	2	6	
Ql	017	6	4	4	2	2	2	6	1	2	3	2	6	6	2	2	2	2	1	2	2	6	6	6	2	3	2	2	
Qf	018	4	4	4	6	2	6	4	5	6	6	6	6	6	6	6	6	6	6	6	6	6	4	4	2	6	6	2	
Qa	019	4	4	4	4	4	4	4	6	4	4	6	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	2	
E	020	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	1
U	021	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	1
T	022	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1
To	023	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1
Tm	024	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	
Th	025	2	3	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	1	
Tv	026	4	4	4	4	4	6	4	6	6	6	2	6	4	4	4	4	4	6	4	4	4	6	4	6	4	4	6	
V	027	1	1	4	1	1	1	1	2	1	2	2	2	1	1	3	3	6	2	3	6	1	1	6	4	4	1	6	
Vp	028	1	1	4	1	1	1	1	2	1	2	2	2	1	1	3	3	6	2	3	6	1	1	6	4	4	1	6	
Vc	029	1	1	4	1	1	1	1	2	1	2	2	2	1	1	3	3	6	2	3	6	1	1	6	4	4	1	6	

Soil		Crops																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
Z	030	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Zo	031	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Zm	032	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Zt	033	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Zg	034	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
S	035	6	4	4	4	6	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
So	036	6	4	4	4	6	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
Sm	037	6	4	4	4	6	6	6	6	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	2
Sg	038	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
Y	039	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	2
Yh	040	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	2
Yk	041	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	2
Yy	042	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
Yl	043	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	2
Yt	044	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
X	045	1	4	4	1	1	1	1	1	1	4	4	4	4	1	1	1	1	1	2	1	4	4	4	4	4	2	1	1
Xh	046	1	4	4	1	1	1	1	1	1	4	4	4	4	1	1	1	1	1	2	1	4	4	4	4	4	2	1	1
Xk	047	1	4	4	3	1	1	1	1	1	4	4	4	4	3	3	3	4	1	3	4	4	4	4	4	6	3	1	
Xy	048	6	4	4	4	6	6	6	6	6	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	4	2
Xl	049	1	4	4	1	1	1	1	1	1	4	4	4	4	1	1	1	1	1	1	1	4	4	4	4	4	2	1	1
K	050	1	2	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	2	4	1	1	1	
Kh	051	1	2	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	2	4	1	1	1	
Kk	052	1	3	4	3	1	1	1	1	1	2	6	3	1	3	3	3	2	1	3	2	1	1	2	4	2	3	1	
Kl	053	1	1	4	1	1	1	1	1	1	1	2	1	1	1	1	1	3	1	1	3	1	1	5	4	1	1	1	
C	054	1	2	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	6	4	1	1	1	
Ch	055	1	2	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	6	4	1	1	1	
Ck	056	1	3	4	3	1	1	1	1	1	2	6	3	1	3	3	3	2	1	3	2	1	1	6	4	2	3	1	
Cl	057	1	1	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	6	4	1	1	1	
Cg	058	1	2	4	1	1	1	1	1	1	1	2	1	1	1	1	1	3	1	1	3	1	1	2	4	1	1	1	
H	059	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hh	060	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hc	061	1	3	3	3	1	1	1	1	1	2	6	3	1	3	3	3	2	1	3	2	1	1	6	4	1	3	1	
Hl	062	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Soil		Crops																										
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr
Hg	063	6	1	1	6	6	6	6	6	6	4	4	6	2	6	6	6	6	4	6	6	2	4	6	6	4	6	1
M	064	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mo	065	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mg	066	6	1	1	6	6	6	6	6	6	4	4	6	2	6	6	6	6	4	3	6	2	4	6	6	4	6	1
B	067	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1
Be	068	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1
Bd	069	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1
Bh	070	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bg	071	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1
Bx	072	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
Bk	073	1	3	3	3	1	1	1	1	1	2	6	3	1	3	3	3	3	1	3	3	1	1	6	6	1	3	1
Bc	074	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bv	075	1	1	1	1	1	1	1	2	1	2	2	2	1	1	1	1	1	1	3	1	1	1	2	4	1	1	1
Bf	076	2	6	2	2	2	2	2	2	2	6	6	6	2	2	2	2	2	3	2	2	2	2	6	3	2	2	1
L	077	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lo	078	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lc	079	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lk	080	1	3	3	3	1	1	1	1	1	2	2	3	1	3	3	3	3	1	3	3	1	1	2	2	1	3	1
Lv	081	1	1	3	1	1	1	1	2	1	2	2	2	1	1	1	1	3	1	3	3	1	1	2	4	1	1	1
Lf	082	3	6	3	3	3	3	3	3	3	6	6	6	3	3	3	3	6	1	3	6	3	3	6	1	2	3	1
La	083	1	2	1	1	1	1	1	1	1	2	1	2	2	1	1	1	4	1	1	4	2	1	3	2	4	1	1
Lp	084	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	2
Lg	085	6	1	6	6	6	6	6	6	6	4	4	6	2	6	6	6	6	4	6	6	2	4	6	6	4	6	1
D	086	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
De	087	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dd	088	2	1	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1
Dg	089	6	1	6	6	6	6	6	6	6	4	6	4	6	6	6	6	6	4	6	6	6	4	6	6	4	6	1
P	090	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	2
Po	091	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	2
Pl	092	2	4	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1	4	2	2
Pf	093	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	2
Ph	094	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
Pp	095	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2

Soil		Crops																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
Pg	096	4	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
W	097	2	1	2	2	2	2	2	2	2	6	2	2	2	2	2	2	2	2	2	2	2	2	2	6	3	2	1	
We	098	2	1	2	2	2	2	2	2	2	6	2	2	2	2	2	2	2	2	2	2	2	2	6	3	2	1		
Wd	099	6	1	6	6	6	6	6	6	6	6	6	2	6	6	6	6	6	6	6	6	2	6	6	6	2	6	1	
Wm	100	2	1	2	2	2	2	2	2	2	6	2	2	2	2	2	2	2	2	2	2	2	2	6	3	2	1		
Wh	101	6	1	2	2	2	6	6	6	6	6	6	2	2	2	2	2	6	2	2	2	2	2	6	2	2	1		
Ws	102	4	6	6	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	6	6	4	4	4	4	2	
Wx	103	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	
A	104	3	1	1	3	3	1	3	1	1	3	1	3	3	3	3	3	3	3	3	3	3	3	3	1	2	3	1	
Ao	105	3	1	1	3	3	1	3	1	1	3	1	3	3	3	3	3	3	3	3	3	3	3	3	1	2	3	1	
Af	106	3	6	1	3	3	1	3	1	1	3	1	3	3	3	3	3	3	3	3	3	3	3	3	1	4	3	1	
Ah	107	3	1	1	3	3	1	3	1	1	3	1	3	3	3	3	3	3	3	3	3	3	3	3	1	2	3	1	
Ap	108	6	3	5	6	6	5	6	5	5	6	5	6	6	6	6	6	6	6	6	6	6	6	5	4	6	2		
Ag	109	4	1	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	6	4	4	4	4	4	1	
N	110	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Ne	111	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Nd	112	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	
Nh	113	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	
F	114	2	2	1	2	2	3	2	3	3	2	3	2	2	2	2	2	3	2	2	3	2	2	2	3	2	2	1	
Fo	115	2	2	1	2	2	3	2	3	3	2	3	2	2	2	2	2	3	2	2	3	2	2	2	3	2	2	1	
Fx	116	2	2	1	2	2	3	2	3	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	3	4	2	1	
Fr	117	3	3	1	3	3	1	3	1	1	3	1	3	3	3	3	3	3	3	3	3	3	3	3	1	3	3	1	
Fh	118	3	3	1	3	3	1	3	1	1	3	1	3	3	3	3	3	3	3	3	3	3	3	3	1	2	3	1	
Fa	119	4	4	6	6	4	2	4	2	2	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	2	
Fp	120	6	2	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	2	
O	121	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	1	
Oe	122	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	1	
Od	123	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	2	
Ox	124	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	
IA	125	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
IB	126	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
IC	127	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
ID	128	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	

Soil		Crops																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
IE	129	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
IF	130	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
J	146	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	1	1	
Je	147	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	1	1	
Jc	148	1	3	3	3	1	1	1	1	1	3	3	3	1	3	3	3	3	3	3	3	1	1	3	4	4	3	1	
Jd	149	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	4	1	1	
Jt	150	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	

Note: 1 = 100% S1, 2 = 100% S2, 3 = 50% S1 and 50% S2, 4 = 100% NS, 5 = 50% S1 and 50% NS, 6 = 50% S2 and 50% NS

APPENDIX X

FAO '74 SOIL UNIT RATINGS FOR RAINFED CONDITIONS (at LOW INPUT LEVEL)

Soil		Crops																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
G	001	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	6	4	4	4	4	1
Ge	002	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	6	4	4	4	4	1
Gc	003	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	4	4	4	4	4	1
Gd	004	4	3	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4	1
Gm	005	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	6	4	4	4	4	1
Gh	006	6	1	6	4	6	6	6	4	6	4	4	4	6	4	4	4	4	4	4	4	6	4	6	4	4	4	4	1
Gp	007	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
Gx	008	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
R	009	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Re	010	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rc	011	1	3	3	3	1	1	1	1	1	2	6	3	1	3	3	3	2	1	3	2	1	1	2	6	1	3	1	
Rd	012	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
Rx	013	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
I	014	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
Q	015	4	4	4	4	2	2	4	2	2	2	2	6	6	4	2	2	2	2	2	2	6	6	6	4	2	4	6	
Qc	016	4	4	4	4	2	2	4	2	2	2	2	6	6	4	2	2	2	2	2	2	6	6	6	4	2	4	6	
Ql	017	4	4	4	4	2	2	4	2	2	2	2	6	6	4	2	2	2	2	2	2	6	6	6	4	2	4	2	
Qf	018	4	4	4	4	2	6	4	2	6	6	2	6	6	4	6	6	6	2	6	6	6	4	4	4	6	4	2	
Qa	019	4	4	4	4	4	4	4	6	4	4	6	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	2	
E	020	6	4	4	4	6	2	6	6	2	4	4	4	6	4	4	4	4	6	4	4	6	4	4	4	4	2	4	1
U	021	4	4	6	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	1
T	022	2	1	1	2	2	1	2	1	1	2	1	2	2	2	2	2	2	2	2	2	2	2	3	1	2	2	1	
To	023	2	1	1	2	2	1	2	1	1	2	1	2	2	2	2	2	2	2	2	2	2	2	3	1	2	2	1	
Tm	024	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	
Th	025	2	3	2	2	2	3	2	3	3	2	3	2	3	2	2	2	2	2	2	2	3	2	3	3	6	2	1	
Tv	026	4	4	4	4	4	6	4	6	6	6	2	6	4	4	4	4	4	6	4	4	4	6	6	6	4	4	6	
V	027	6	2	4	6	6	6	6	6	6	4	4	4	2	6	6	6	6	4	6	6	2	2	2	4	4	6	6	
Vp	028	6	2	4	6	6	6	6	6	6	4	4	4	2	6	6	6	6	4	6	6	2	2	2	4	4	6	6	
Vc	029	6	2	4	6	6	6	6	6	6	4	4	4	2	6	6	6	6	4	6	6	2	2	6	4	4	6	6	

Soil		Crops																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
Z	030	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Zo	031	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Zm	032	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Zt	033	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Zg	034	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
S	035	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
So	036	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
Sm	037	6	4	4	4	6	6	6	6	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	2
Sg	038	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
Y	039	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	2
Yh	040	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	2
Yk	041	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	2
Yy	042	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
Yl	043	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	2
Yt	044	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
X	045	1	4	4	1	1	1	1	1	1	4	4	4	4	1	1	1	1	1	2	1	4	4	4	4	2	1	1	1
Xh	046	1	4	4	1	1	1	1	1	1	4	4	4	4	1	1	1	1	1	2	1	4	4	4	4	2	1	1	1
Xk	047	1	4	4	2	1	1	1	1	1	4	4	4	4	2	2	2	4	1	2	4	4	4	4	4	6	2	1	1
Xy	048	6	4	4	4	6	6	6	6	6	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	4	2
Xl	049	1	4	4	1	1	1	1	1	1	4	4	4	4	1	1	1	1	1	1	1	4	4	4	4	2	1	1	1
K	050	1	2	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	2	4	1	1	1	1
Kh	051	1	2	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	2	4	1	1	1	1
Kk	052	1	2	4	2	1	1	1	1	1	4	6	2	1	2	2	2	2	1	2	2	1	1	4	4	2	2	1	1
Kl	053	1	1	4	1	1	1	1	1	1	1	2	1	1	1	1	1	3	1	1	3	1	1	5	4	1	1	1	1
C	054	1	2	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	6	4	1	1	1	1
Ch	055	1	2	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	6	4	1	1	1	1
Ck	056	1	2	4	2	1	1	1	1	1	4	4	2	1	2	2	2	2	1	2	2	1	1	4	4	2	2	1	1
Cl	057	1	1	4	1	1	1	1	1	1	1	6	1	1	1	1	1	2	1	1	2	1	1	6	4	1	1	1	1
Cg	058	1	2	4	1	1	1	1	1	1	1	2	1	1	1	1	1	3	1	1	3	1	1	2	4	1	1	1	1
H	059	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hh	060	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hc	061	1	2	2	2	1	1	1	1	1	4	4	2	1	2	2	2	2	1	2	2	1	1	4	4	1	2	1	1
Hl	062	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Soil		Crops																										
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr
Hg	063	6	1	1	6	6	6	6	6	6	4	4	6	2	6	6	6	6	4	6	6	2	4	6	6	4	6	1
M	064	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mo	065	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mg	066	6	1	1	6	6	6	6	6	6	4	4	6	2	6	6	6	6	4	3	6	2	4	6	6	4	6	1
B	067	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1
Be	068	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1
Bd	069	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
Bh	070	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1
Bg	071	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1
Bx	072	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
Bk	073	1	2	2	2	1	1	1	1	1	4	4	2	1	2	2	2	2	1	2	2	1	1	4	4	1	2	1
Bc	074	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bv	075	2	1	2	3	2	2	2	6	2	6	6	6	3	3	3	3	3	2	2	3	3	3	2	4	2	3	1
Bf	076	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	2	6	6	1
L	077	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lo	078	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lc	079	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lk	080	1	2	2	2	1	1	1	1	1	4	4	2	1	2	2	2	2	1	2	2	1	1	4	4	1	2	1
Lv	081	2	1	2	3	2	2	2	6	2	6	6	2	3	3	3	3	2	2	2	2	3	3	6	4	2	3	1
Lf	082	2	6	2	2	2	2	2	2	2	6	6	6	2	2	2	2	6	2	2	6	2	2	6	1	6	2	1
La	083	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	2	2	4	2	2	2	2	4	2	1
Lp	084	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	2
Lg	085	6	1	6	6	6	6	6	6	6	4	4	6	2	6	6	6	6	4	6	6	2	4	6	6	4	6	1
D	086	2	1	2	3	2	3	2	3	3	1	1	1	1	3	1	1	3	1	3	3	1	3	1	1	2	3	1
De	087	2	1	2	3	2	3	2	3	3	1	1	1	1	3	1	1	3	1	3	3	1	3	1	1	2	3	1
Dd	088	4	2	2	2	4	2	4	2	2	2	2	2	2	2	2	2	2	4	2	2	2	2	2	2	6	2	1
Dg	089	6	1	6	6	4	6	6	6	6	4	6	4	6	6	6	6	6	4	6	6	6	4	6	6	4	6	1
P	090	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	2
Po	091	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	2
Pl	092	6	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	2	6	6	6	6	6	1	4	6	2
Pf	093	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	2
Ph	094	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
Pp	095	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2

Soil		Crops																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
Pg	096	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
W	097	2	1	2	2	2	2	2	2	2	2	6	2	2	2	2	2	2	2	2	2	2	2	2	6	2	2	2	1
We	098	2	1	2	2	2	2	2	2	2	2	6	2	2	2	2	2	2	2	2	2	2	2	6	2	2	2	1	
Wd	099	6	2	6	6	6	6	6	6	6	6	6	2	6	6	6	6	6	6	6	6	2	6	6	6	6	6	1	
Wm	100	2	1	2	2	2	2	2	2	2	2	6	2	2	2	2	2	2	2	2	2	2	2	6	2	2	2	1	
Wh	101	6	2	2	6	4	6	6	6	6	6	6	2	6	6	6	6	6	6	6	6	2	6	6	6	6	6	1	
Ws	102	4	6	6	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	6	6	4	4	4	4	2	
Wx	103	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	
A	104	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	6	2	1	
Ao	105	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	6	2	1	
Af	106	2	6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	2	2	1	
Ah	107	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	6	2	2	1	
Ap	108	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	2	
Ag	109	4	3	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	6	4	4	4	4	4	1	
N	110	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	
Ne	111	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	
Nd	112	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	
Nh	113	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	
F	114	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	6	2	1	
Fo	115	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	6	2	1	
Fx	116	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	2	1		
Fr	117	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	
Fh	118	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	6	2	1		
Fa	119	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	
Fp	120	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	2	
O	121	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	1	
Oe	122	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	4	4	1	
Od	123	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	
Ox	124	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	
IA	125	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
IB	126	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
IC	127	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
ID	128	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	

Soil		Crops																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
IE	129	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
IF	130	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
J	146	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	1	1	
Je	147	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	1	1	
Jc	148	1	3	3	3	1	1	1	1	1	3	3	3	1	3	3	3	3	3	3	3	1	1	3	4	4	3	1	
Jd	149	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	4	2	1	
Jt	150	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	

Note: 1 = 100% S1, 2 = 100% S2, 3 = 50% S1 and 50% S2, 4 = 100% NS, 5 = 50% S1 and 50% NS, 6 = 50% S2 and 50% NS

APPENDIX X

FAO '74 SOIL UNIT MODIFICATION RATINGS FOR GRAVITY IRRIGATION (at HIGH INPUT LEVEL)

Soil		CROPS																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
Q	015	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Qc	016	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Ql	017	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Qf	018	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Qa	019	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
E	020	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Tv	026	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Yy	042	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Yl	043	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Xy	048	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Xl	049	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Kk	052	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Kl	053	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Ck	056	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Cl	057	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Bk	073	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
P	090	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Po	091	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
all	092	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Pf	093	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Ph	094	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Pp	095	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Pg	096	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
A	104	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Ao	105	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Af	106	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Ah	107	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Ap	108	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Ag	109	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
N	110	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3

Soil		CROPS																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
Ne	111	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Nd	112	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Nh	113	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
F	114	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Fo	115	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Fx	116	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Fr	117	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Fh	118	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Fa	119	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Fp	120	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
O	121	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Oe	122	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Od	123	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Ox	124	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Note: 1 = 100% S1, 2 = 100% S2, 3 = 50% S1 and 50% S2, 4 = 100% NS, 5 = 50% S1 and 50% NS, 6 = 50% S2 and 50% NS

APPENDIX X

FAO '74 SOIL UNIT RATINGS FOR DRAINED SOILS UNDER RAINFED CONDITIONS (at HIGH INPUT LEVEL)

Soil		Crops																											
Unit	Code	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr	
G	001	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	
Ge	002	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	
Gc	003	1	3	3	3	1	1	1	1	1	2	6	3	1	3	3	3	3	2	3	3	1	2	6	6	2	3	1	
Gd	004	3	3	3	3	3	3	3	3	3	2	2	3	3	3	3	3	3	2	3	3	3	2	3	3	2	3	1	
Gm	005	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	
Gh	006	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	
Gp	007	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	2
Gx	008	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
Zg	034	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Sg	038	6	4	4	4	6	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
Hg	063	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	
Mg	066	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	
Bg	071	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	
Lg	085	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	
Dg	089	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	
Pg	096	4	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	
Ag	109	3	1	1	3	3	1	3	1	1	2	2	3	3	3	3	3	3	2	3	3	3	2	3	1	2	3	1	

Note: 1 = 100% S1, 2 = 100% S2, 3 = 50% S1 and 50% S2, 4 = 100% NS, 5 = 50% S1 and 50% NS, 6 = 50% S2 and 50% NS

APPENDIX XI

FAO '74 SOIL PHASE RATINGS FOR RAINFED CONDITIONS (at HIGH INPUT LEVEL)

Soil Phase	Crops																										
	wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr
STONY	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	2	6	4	4
LITHIC	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
PETRIC	3	1	6	1	1	1	1	1	1	1	3	3	3	3	3	3	3	1	3	1	3	3	3	3	3	3	1
PETROCALCIC	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
PETROGYPSIC	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
PETROFERRIC	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
PHREATIC	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	6	1	1
FRAGIPAN	8	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1
DURIPAN	9	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	6	3	3	1
SALINE	10	6	4	4	6	3	6	4	6	4	4	4	6	4	4	4	4	4	4	4	4	3	4	4	4	4	3
SODIC	11	3	3	4	3	3	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	3
SHIFTING	12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
ROCK DEB	13	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
OUTCROPS	14	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
DUNES	15	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
SALT/FLS	16	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
LAKES	17	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
ICE CAPS	18	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Note: 1 = 100% S1, 2 = 100% S2, 3 = 50% S1 and 50% S2, 4 = 100% NS, 5 = 50% S1 and 50% NS, 6 = 50% S2 and 50% NS

APPENDIX XI

FAO '74 SOIL PHASE RATINGS FOR RAINFED CONDITIONS (at LOW INPUT LEVEL)

Soil Phase		Crops																										
		wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr
STONY	1	2	4	2	2	2	2	2	2	2	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2
LITHIC	2	6	4	6	6	6	6	6	6	6	4	6	6	6	6	6	6	6	6	6	6	6	6	4	4	6	6	2
PETRIC	3	1	6	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	1	3	1	3	3	3	3	1	3	1
PETROCALCIC	4	3	6	3	3	3	3	3	3	3	6	6	6	6	6	6	6	3	6	6	6	6	6	6	6	3	6	3
PETROGYPSIC	5	3	6	3	3	3	3	3	3	3	6	6	6	6	6	6	6	3	6	6	6	6	6	6	6	6	6	3
PETROFERRIC	6	3	6	3	3	3	3	3	3	3	6	6	6	6	6	6	6	3	6	6	6	6	6	6	6	6	6	3
PHREATIC	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	6	1	1
FRAGIPAN	8	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1
DURIPAN	9	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	6	3	3	1
SALINE	10	6	4	4	6	3	6	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	3
SODIC	11	3	3	4	3	3	3	4	1	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	3
SHIFTING	12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
ROCK DEB	13	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
OUTCROPS	14	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
DUNES	15	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
SALT/FLS	16	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
LAKES	17	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
ICE CAPS	18	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Note: 1 = 100% S1, 2 = 100% S2, 3 = 50% S1 and 50% S2, 4 = 100% NS, 5 = 50% S1 and 50% NS, 6 = 50% S2 and 50% NS

APPENDIX XI

FAO '74 SOIL PHASE RATINGS FOR GRAVITY IRRIGATION (at HIGH INPUT LEVEL)

Soil Phase		Crops																										
		wh	wr	dr	mz	by	sg	ry	pm	fx	wp	ca	sp	su	sb	pb	ch	cw	gn	sy	sf	rp	ct	ba	op	ol	al	gr
STONY	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
LITHIC	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
PETRIC	3	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	1
PETROCALCIC	4	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
PETROGYPSIC	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
PETROFERRIC	6	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
PHREATIC	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	6	1
FRAGIPAN	8	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	1
DURIPAN	9	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	1
SALINE	10	6	4	4	6	2	6	4	6	4	4	4	4	6	4	4	4	4	4	4	4	4	2	4	4	4	4	3
SODIC	11	2	3	4	2	2	2	4	2	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	4	4	4	3
SHIFTING	12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
ROCK DEB	13	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
OUTCROPS	14	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
DUNES	15	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
SALT/FLS	16	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
LAKES	17	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
ICE CAPS	18	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Note: 1 = 100% S1, 2 = 100% S2, 3 = 50% S1 and 50% S2, 4 = 100% NS, 5 = 50% S1 and 50% NS, 6 = 50% S2 and 50% NS

APPENDIX XII

FALLOW PERIOD REQUIREMENTS

Thermal Regime (Annual mean temperature)		> 25°C					20-25°C				
Moisture Regime (LGP, days)		<90	90-120	120-180	180-270	>270	<90	90-120	120-180	180-270	>270
FAO Soil Units	Crop Groups										
J, Je, Jc	Cereals	30	30	30	30	30	30	30	30	30	
	Legumes	30	30	30	30	30	30	30	30	30	
	Roots/Tubers	30	30	30	30	30	30	30	30	30	
	Long term Annuals and Perennials	30	30	30	30	30	30	30	30	30	
G, Ge, Gc, Gm, Gh	Cereals	40	40	40	40	40	40	40	40	40	
	Legumes	40	40	40	40	40	40	40	40	40	
	Roots/Tubers	40	40	40	40	40	40	40	40	40	
	Long term Annuals and Perennials	40	40	40	40	40	40	40	40	40	
R, Re, Rc, E, Tm, Th, V, Vp, Vc, K, Kh, Kk, Kl, C, Ch, Ck, Cl, Cg, H, Hh, Hc, Hl, Hg, M, Mo, Mg, B, Be, Bh, Bg, Bx, Bk, Bc, Bv, L, Lo, Lc, Lk, Lv, Lg, D, De, Wh, Ah, N, Ne, Nh, Fh	Cereals	75	70	65	65	75	70	65	60	60	
	Legumes	75	70	65	65	75	70	65	60	60	
	Roots/Tubers	75	70	65	65	75	70	65	60	60	
	Long term Annuals and Perennials	75	70	65	65	75	70	65	60	60	
Z, Zo, Zm, Zg, S, So, Sm, Sg, Y, Yh, Yk, Yy, Yt	Cereals	80	75	70	70	80	75	70	65	65	
	Legumes	80	75	70	70	80	75	70	65	65	
	Roots/Tubers	80	75	70	70	80	75	70	65	65	
	Long term Annuals and Perennials	80	75	70	70	80	75	70	65	65	
X, Xh, Xk, Xl	Cereals	80	75	70	70	80	75	70	65	65	
	Legumes	80	75	70	70	80	75	70	65	65	
	Roots/Tubers	85	80	75	75	85	80	75	70	70	
	Long term Annuals and Perennials	90	85	80	80	90	85	80	75	75	
T, To Bd, Lf, La, Dd, Dg, W, We, Wm, A, Ao, Af, Ag, Nd, F, Fo, Fx, Fr, Jd, Jt	Cereals	85	80	75	75	85	80	75	70	70	
	Legumes	85	80	75	75	85	80	75	70	70	
	Roots/Tubers	85	80	75	75	85	80	75	70	70	
	Long term Annuals and Perennials	85	80	75	75	85	80	75	70	70	
Q, Qc, Ql, Bf	Cereals	85	80	75	75	85	80	75	70	70	
	Legumes	85	80	75	75	85	80	75	70	70	
	Roots/Tubers	90	85	80	80	90	85	80	75	75	
	Long term Annuals and Perennials	90	85	80	80	90	85	80	75	75	
Gd, Gp, Gx, Rd, Rx, I, Qf, Qa, U, Tv, Xy, Lp, P, Po, Pl, Pf, Ph, Pp, Pg, Wd, Ws, Wx, Ap, Fa, Fp, O, Oe, Od, Ox	Cereals	90	85	80	80	90	85	80	75	75	
	Legumes	90	85	80	80	90	85	80	75	75	
	Roots/Tubers	90	85	80	80	90	85	80	75	75	
	Long term Annuals and Perennials	90	85	80	80	90	85	80	75	75	

Thermal Regime (Annual mean temperature)		15-20°C					<15°C				
Moisture Regime (LGP days)		<90	90-120	120-180	180-270	>270	<90	90-120	120-180	180-270	>270
FAO Soil Units	Crop Groups										
J, Je, Jc	Cereals	30	30	30	30	30	30	30	30	30	
	Legumes	30	30	30	30	30	30	30	30	30	
	Roots/Tubers	30	30	30	30	30	30	30	30	30	
	Long term Annuals and Perennials	30	30	30	30	30	30	30	30	30	
G, Ge, Gc, Gm, Gh	Cereals	40	40	40	40	40	40	40	40	40	
	Legumes	40	40	40	40	40	40	40	40	40	
	Roots/Tubers	40	40	40	40	40	40	40	40	40	
	Long term Annuals and Perennials	40	40	40	40	40	40	40	40	40	
R, Re, Rc, E, Tm, Th, V, Vp, Vc, K, Kh, Kk, Kl, C, Ch, Ck, Cl, Cg, H, Hh, Hc, Hl, Hg, M, Mo, Mg, B, Be, Bh, Bg, Bx, Bk, Bc, Bv, L, Lo, Lc, Lk, Lv, Lg, D, De, Wh, Ah, N, Ne, Nh, Fh	Cereals	70	65	60	60	70	75	70	65	65	75
	Legumes	70	65	60	60	70	75	70	65	65	75
	Roots/Tubers	70	65	60	60	70	75	70	65	65	75
	Long term Annuals and Perennials	70	65	60	60	70	75	70	65	65	75
Z, Zo, Zm, Zg, S, So, Sm, Sg, Y, Yh, Yk, Yy, Yt	Cereals	75	70	65	65	75	80	75	70	70	80
	Legumes	75	70	65	65	75	80	75	70	70	80
	Roots/Tubers	75	70	65	65	75	80	75	70	70	80
	Long term Annuals and Perennials	75	70	65	65	75	80	75	70	70	80
X, Xh, Xk, Xl	Cereals	75	70	65	65	75	80	75	70	70	80
	Legumes	75	70	65	65	75	80	75	70	70	80
	Roots/Tubers	80	75	70	70	80	85	80	75	75	85
	Long term Annuals and Perennials	85	80	75	75	85	90	85	80	80	90
T, To Bd, Lf, La, Dd, Dg, W, We, Wm, A, Ao, Af, Ag, Nd, F, Fo, Fx, Fr, Jd, Jt	Cereals	80	75	70	70	80	85	80	75	75	85
	Legumes	80	75	70	70	80	85	80	75	75	85
	Roots/Tubers	80	75	70	70	80	85	80	75	75	85
	Long term Annuals and Perennials	80	75	70	70	80	85	80	75	75	85
Q, Qc, Ql, Bf	Cereals	80	75	70	70	80	85	80	75	75	85
	Legumes	80	75	70	70	80	85	80	75	75	85
	Roots/Tubers	85	80	75	75	85	90	85	80	80	90
	Long term Annuals and Perennials	85	80	75	75	85	90	85	80	80	90
Gd, Gp, Gx, Rd, Rx, I, Qf, Qa, U, Tv, Xy, Lp, P, Po, Pl, Pf, Ph, Pp, Pg, Wd, Ws, Wx, Ap, Fa, Fp, O, Oe, Od, Ox	Cereals	85	80	75	75	85	90	85	80	80	90
	Legumes	85	80	75	75	85	90	85	80	80	90
	Roots/Tubers	85	80	75	75	85	90	85	80	80	90
	Long term Annuals and Perennials	85	80	75	75	85	90	85	80	80	90

APPENDIX XIII

SOIL MOISTURE STORAGE CAPACITY FOR THE SOIL UNITS OF THE SOIL MAP OF THE WORLD

The growing period for most crops continues beyond the rainy season and, to a greater or lesser extent, crops mature on moisture stored in the soil profile. However, the amount of soil moisture stored in the soil profile, and available to a crop, varies, e.g., with depth of the soil profile, the soil physical characteristics, and the rooting pattern of the crop. Depletion of soil moisture reserves causes the actual evapotranspiration to fall short of the potential rate. Soil moisture storage capacity of soils (*S_{max}*) depends on soil physical and chemical characteristics, but above all on effective soil depth or volume. For the soil units of the Legend of the Soil Map of the World (FAO, 1974), FAO has developed procedures for the estimation of *S_{max}* (FAO, 1995c).

As a first step the soil group and soil units are grouped in eight sets which reflect fundamental differences in soil depth, textural changes with depth, influence of parent material or seasonal flooding conditions. These sets are:

1. *Histosols, Fluvisols and Gleysols*: which are considered as wetlands or water collecting sites.
2. *Andosols*: which due to parent material influence have a very high *S_{max}* (except Vitric Andosols).
3. *Vertisols*: specific characteristics set this group of soils apart.
4. *Lithosols and miscellaneous land units*: Lithosols and 'rock' units are characterized by a very limited soil depth.
5. *Rendzinas and Rankers*: both these soil groups are shallow by definition.
6. *Soil groups and soil units with no implied clay increase with depth*: this group combines soils in which the topsoil texture is considered representative of the whole profile. These are: Solonchaks, Regosols, Podzols, Cambisols, Arenosols, Vitric Andosols, Greyzems and the non-luvisc soil units of the Xerosols, Yermosols, Kastanozems, Chernozems and Phaeozems.
7. *Soil groups and soil units with an implied clay increase with depth*: this set combines soils in which subsoil texture is finer than the topsoil texture. These are Solonetz, Podzoluvisols, Nitisols, Acrisols, Ferralsols and luvisc units of the Xerosols, Yermosols, Kastanozems, Chernozems and Phaeozems.
8. *Planosols*: This soil group is considered to have a fine textured subsoil regardless of the topsoil texture which separates these soils from those discussed under 6 and 7.

Water availability to plants grown on Histosols, Gleysols and Fluvisols is mainly a function of groundwater or surface water levels and flooding. Although an *S_{max}* value can be deduced for these soils, this is largely irrelevant for practical purposes. Hence these soil groups are considered here as 'water collecting sites' and no *S_{max}* is determined for them. For tropical soils (Ferralsols, Acrisols, Nitisols, Ferralic Cambisols and Ferric Luvisols) *S_{max}* is decreased by 10% as compared to similar textural classes for other soils.

Gravel, stones, boulders and rock fragments when present in the profile reduce considerably the capacity of a soil to store moisture. The Legend of the Soil Map of the World uses this criterion when defining the stony phase reflecting the presence of coarse fragments in the surface layers or at the surface to an extent that it makes the use of mechanized equipment impracticable. Soil groups and units such as Vitric Andosols, Rendzinas and Lithosols generally

contain a significant amount of gravel, while in other soils such as Ferralsols (stone line), Regosols, Acrisols, and soils with a petrocalcic or petrogypsic phase gravel occurrence is more common but largely dependent on local conditions. In the present general approach it is suggested to reduce *S_{max}* by 50% when a stony or petric phase is present in a mapping unit of the DSMW. These adjustments are location specific and modify the evaluation of the respective soil units listed in the tables below (see Table 6 in Chapter 3).

Soil moisture storage capacity (*S_{max}*) classes derived for FAO soil units of Legend '74

FAO Legend '74 Soil Unit	SLU	coarse		medium		fine		FAO Legend '74 Soil Unit	SLU	coarse		medium		fine	
		mm	CL	mm	CL	mm	CL			mm	CL	mm	CL		
Eutric Gleysols	Ge	n.a.	1	n.a.	1	n.a.	1	Eutric Cambisols	Be	106	3	180	1	165	1
Calcaric Gleysols	Gc	n.a.	1	n.a.	1	n.a.	1	Dystric Cambisols	Bd	106	3	180	1	165	1
Dystric Gleysols	Gd	n.a.	1	n.a.	1	n.a.	1	Humic Cambisols	Bh	106	3	180	1	165	1
Mollic Gleysols	Gm	n.a.	1	n.a.	1	n.a.	1	Gleyic Cambisols	Bg	106	3	180	1	165	1
Humic Gleysols	Gh	n.a.	1	n.a.	1	n.a.	1	Gelic Cambisols	Bx	106	3	180	1	165	1
Plinthic Gleysols	Gp	n.a.	1	n.a.	1	n.a.	1	Calcic Cambisols	Bk	106	3	180	1	165	1
Gelic Gleysols	Gx	n.a.	1	n.a.	1	n.a.	1	Chromic Cambisols	Bc	106	3	180	1	165	1
Eutric Regosols	Re	106	3	180	1	165	1	Vertic Cambisols	Bv	106	3	180	1	165	1
Calcaric Regosols	Rc	106	3	180	1	165	1	Ferralic Cambisols	Bf	95	3	162	1	148	1
Dystric Regosols	Rd	106	3	180	1	165	1	Orthic Luvisols	Lo	162	1	180	1	175	1
Gelic Regosols	Rx	106	3	180	1	165	1	Chromic Luvisols	Lc	162	1	180	1	175	1
Lithosols	I	13	6	19	6	18	6	Calcic Luvisols	Lk	162	1	180	1	175	1
Cambic Arenosols	Qc	106	3	180	1	165	1	Vertic Luvisols	Lv	162	1	180	1	175	1
Luvic Arenosols	Ql	106	3	180	1	165	1	Ferric Luvisols	Lf	146	1	162	1	157	1
Ferralic Arenosols	Qf	106	3	180	1	165	1	Albic Luvisols	La	162	1	180	1	175	1
Albic Arenosols	Qa	106	3	180	1	165	1	Plinthic Luvisols	Lp	162	1	180	1	175	1
Rendzinas	E	39	5	57	5	53	5	Gleyic Luvisols	Lg	162	1	180	1	175	1
Rankers	U	39	5	57	5	53	5	Eutric Podzoluvisols	De	162	1	180	1	175	1
Ochric Andosols	To	200	1	200	1	200	1	Dystric Podzoluvisol	Dd	162	1	180	1	175	1
Mollic Andosols	Tm	200	1	200	1	200	1	Gleyic Podzoluvisols	Dg	162	1	180	1	175	1
Humic Andosols	Th	200	1	200	1	200	1	Orthic Podzols	Po	106	3	180	1	165	1
Vitric Andosols	Tv	200	1	200	1	200	1	Leptic Podzols	Pl	106	3	180	1	165	1
Pellic Vertisols	Vp	135	2	135	2	135	2	Ferric Podzols	Pf	106	3	180	1	165	1
Chromic Vertisols	Vc	135	2	135	2	135	2	Humic Podzols	Ph	106	3	180	1	165	1
Orthic Solonchaks	Zo	106	3	180	1	165	1	Placic Podzols	Pp	106	3	180	1	165	1
Mollic Solonchaks	Zm	106	3	180	1	165	1	Gleyic Podzols	Pg	106	3	180	1	165	1
Takyric Solonchaks	Zt	106	3	180	1	165	1	Eutric Planosols	We	152	1	169	1	165	1
Gleyic Solonchaks	Zg	106	3	180	1	165	1	Dystric Planosols	Wd	152	1	169	1	165	1
Orthic Solonetz	So	106	3	180	1	165	1	Mollic Planosols	Wm	152	1	169	1	165	1
Mollic Solonetz	Sm	106	3	180	1	165	1	Humic Planosols	Wh	152	1	169	1	165	1
Gleyic Solonetz	Sg	106	3	180	1	165	1	Sodic Planosols	Ws	152	1	169	1	165	1
Haplic Yermosols	Yh	106	3	180	1	165	1	Gelic Planosols	Wx	152	1	169	1	165	1
Calcic Yermosols	Yk	106	3	180	1	165	1	Orthic Acrisols	Ao	146	1	162	1	157	1
Gypsic Yermosols	Yy	106	3	180	1	165	1	Ferric Acrisols	Af	146	1	162	1	157	1
Luvic Yermosols	Yl	162	1	180	1	175	1	Humic Acrisols	Ah	146	1	162	1	157	1
Takyric Yermosols	Yt	106	3	180	1	165	1	Plinthic Acrisols	Ap	146	1	162	1	157	1
Haplic Xerosols	Xh	106	3	180	1	165	1	Gleyic Acrisols	Ag	146	1	162	1	157	1
Calcic Xerosols	Xk	106	3	180	1	165	1	Eutric Nitosols	Ne	146	1	162	1	157	1
Gypsic Xerosols	Xy	106	3	180	1	165	1	Dystric Nitosols	Nd	146	1	162	1	157	1
Luvic Xerosols	Xl	162	1	180	1	175	1	Humic Nitosols	Nh	146	1	162	1	157	1
Haplic Kastanozems	Kh	106	3	180	1	165	1	Orthic Ferralsols	Fo	146	1	162	1	148	1
Calcic Kastanozems	Kk	106	3	180	1	165	1	Xanthic Ferralsols	Fx	146	1	162	1	148	1
Luvic Kastanozems	Kl	162	1	180	1	175	1	Rhodic Ferralsols	Fr	146	1	162	1	148	1
Haplic Chernozems	Ch	106	3	180	1	165	1	Humic Ferralsols	Fh	146	1	162	1	148	1
Calcic Chernozems	Ck	106	3	180	1	165	1	Acric Ferralsols	Fa	146	1	162	1	148	1
Luvic Chernozems	Cl	162	1	180	1	175	1	Plinthic Ferralsols	Fp	146	1	162	1	148	1
Glossic Chernozems	Cg	106	3	180	1	165	1	Eutric Histosols	Oe	n.a.	1	n.a.	1	n.a.	1
Haplic Phaeozems	Hh	106	3	180	1	165	1	Dystric Histosols	Od	n.a.	1	n.a.	1	n.a.	1
Calcaric Phaeozems	Hc	106	3	180	1	165	1	Gelic Histosols	Ox	n.a.	1	n.a.	1	n.a.	1
Luvic Phaeozems	Hl	162	1	180	1	175	1	Eutric Fluvisols	Je	n.a.	1	n.a.	1	n.a.	1
Gleyic Phaeozems	Hg	106	3	180	1	165	1	Calcaric Fluvisols	Jc	n.a.	1	n.a.	1	n.a.	1
Orthic Greyzems	Mo	106	3	180	1	165	1	Dystric Fluvisols	Jd	n.a.	1	n.a.	1	n.a.	1
Gleyic Greyzems	Mg	106	3	180	1	165	1	Thionic Fluvisols	Jt	n.a.	1	n.a.	1	n.a.	1

Soil moisture storage capacity classes derived for FAO soil units of Revised Legend '90

FAO Legend '90 Soil Unit	SLU	coarse		medium		fine		FAO Legend '90 Soil Unit	SLU	coarse		medium		fine	
		mm	CL	mm	CL	mm	CL			mm	CL	mm	CL	mm	CL
Ferric Acrisols	ACf	146	1	162	1	157	1	Eutric Gleysols	GLE	n.a.	1	n.a.	1	n.a.	1
Gleyic Acrisols	ACg	146	1	162	1	157	1	Gelic Gleysols	GLi	n.a.	1	n.a.	1	n.a.	1
Haplic Acrisols	ACH	146	1	162	1	157	1	Calcic Gleysols	GLk	n.a.	1	n.a.	1	n.a.	1
Plinthic Acrisols	ACp	146	1	162	1	157	1	Mollic Gleysols	GLm	n.a.	1	n.a.	1	n.a.	1
Humic Acrisols	ACu	146	1	162	1	157	1	Thionic Gleysols	GLt	n.a.	1	n.a.	1	n.a.	1
Ferric Alisols	ALf	146	1	162	1	157	1	Umbric Gleysols	GLu	n.a.	1	n.a.	1	n.a.	1
Gleyic Alisols	ALg	146	1	162	1	157	1	Gleyic Greyzems	GRg	106	3	180	1	165	1
Haplic Alisols	ALh	146	1	162	1	157	1	Haplic Greyzems	GRh	106	3	180	1	165	1
Stagnic Alisols	ALj	146	1	162	1	157	1	Haplic Gypsisols	GYh	106	3	180	1	165	1
Plinthic Alisols	ALp	146	1	162	1	157	1	Calcic Gypsisols	GYk	106	3	180	1	165	1
Humic Alisols	ALu	146	1	162	1	157	1	Luvic Gypsisols	GYl	162	1	180	1	175	1
Gleyic Andosols	ANg	200	1	200	1	200	1	Petric Gypsisols	GYp	79	4	135	2	123	2
Haplic Andosols	ANh	200	1	200	1	200	1	Fibric Histosols	HSf	n.a.	1	n.a.	1	n.a.	1
Gelic Andosols	ANi	200	1	200	1	200	1	Gelic Histosols	HSi	n.a.	1	n.a.	1	n.a.	1
Mollic Andosols	ANm	200	1	200	1	200	1	Folic Histosols	HSI	n.a.	1	n.a.	1	n.a.	1
Umbric Andosols	ANu	200	1	200	1	200	1	Terric Histosols	HSs	n.a.	1	n.a.	1	n.a.	1
Vitric Andosols	ANz	200	1	200	1	200	1	Thionic Histosols	HSt	n.a.	1	n.a.	1	n.a.	1
Albic Arenosols	ARa	106	3	180	1	165	1	Haplic Kastanozems	KSh	106	3	180	1	165	1
Cambic Arenosols	ARb	106	3	180	1	165	1	Calcic Kastanozems	KSk	106	3	180	1	165	1
Calcaric Arenosols	ARc	106	3	180	1	165	1	Luvic Kastanozems	KSl	162	1	180	1	175	1
Gleyic Arenosols	ARf	106	3	180	1	165	1	Gypsic Kastanozems	KSy	106	3	180	1	165	1
Haplic Arenosols	ARg	106	3	180	1	165	1	Dystric Leptosols	LPd	13	6	19	6	18	6
Luvic Arenosols	ARl	106	3	180	1	165	1	Eutric Leptosols	LPe	13	6	19	6	18	6
Ferralic Arenosols	ARo	106	3	180	1	165	1	Gelic Leptosols	LPi	13	6	19	6	18	6
Aric Anthrosols	ATa	200	1	200	1	200	1	Rendzic Leptosols	LPk	39	5	57	5	53	5
Cumulic Anthrosols	ATc	250	1	250	1	250	1	Mollic Leptosols	LPm	13	6	19	6	18	6
Fimic Anthrosols	ATf	200	1	200	1	200	1	Lithic Leptosols	LPq	13	6	19	6	18	6
Urbic Anthrosols	ATu	200	1	200	1	200	1	Umbric Leptosols	LPu	13	6	19	6	18	6
Gleyic Chernozems	CHg	106	3	180	1	165	1	Albic Luvisols	LVa	162	1	180	1	175	1
Haplic Chernozems	CHh	106	3	180	1	165	1	Ferric Luvisols	LVf	146	1	162	1	157	1
Calcic Chernozems	CHk	106	3	180	1	165	1	Gleyic Luvisols	LVg	162	1	180	1	175	1
Luvic Chernozems	CHl	162	1	180	1	175	1	Haplic Luvisols	LVh	162	1	180	1	175	1
Glossic Chernozems	CHw	106	3	180	1	165	1	Stagnic Luvisols	LVj	162	1	180	1	175	1
Haplic Calcisols	CLh	106	3	180	1	165	1	Calcic Luvisols	LVk	162	1	180	1	175	1
Luvic Calcisols	CLi	162	1	180	1	175	1	Vertic Luvisols	LVv	162	1	180	1	175	1
Petric Calcisols	CLp	79	4	135	2	123	2	Chromic Luvisols	LVx	162	1	180	1	175	1
Calcaric Cambisols	CMc	106	3	180	1	165	1	Albic Lixisols	LXa	146	1	162	1	157	1
Dystric Cambisols	CMd	106	3	180	1	165	1	Ferric Lixisols	LXf	146	1	162	1	157	1
Eutric Cambisols	CMe	106	3	180	1	165	1	Gleyic Lixisols	LXg	146	1	162	1	157	1
Gleyic Cambisols	CMg	106	3	180	1	165	1	Haplic Lixisols	LXh	146	1	162	1	157	1
Gelic Cambisols	CMi	106	3	180	1	165	1	Stagnic Lixisols	LXj	146	1	162	1	157	1
Ferralic Cambisols	CMo	95	3	162	1	148	1	Plinthic Lixisols	LXp	146	1	162	1	157	1
Humic Cambisols	CMu	106	3	180	1	165	1	Haplic Nitisols	NTh	146	1	162	1	157	1
Vertic Cambisols	CMv	106	3	180	1	165	1	Rhodic Nitisols	NTr	146	1	162	1	157	1
Chromic Cambisols	CMx	106	3	180	1	165	1	Humic Nitisols	NTu	146	1	162	1	157	1
Calcaric Fluvisols	FLc	n.a.	1	n.a.	1	n.a.	1	Dystric Podzoluvisol	PDd	162	1	180	1	175	1
Dystric Fluvisols	FLd	n.a.	1	n.a.	1	n.a.	1	Eutric Podzoluvisols	PDe	162	1	180	1	175	1
Eutric Fluvisols	FLe	n.a.	1	n.a.	1	n.a.	1	Gleyic Podzoluvisols	PDg	162	1	180	1	175	1
Mollic Fluvisols	FLm	n.a.	1	n.a.	1	n.a.	1	Gelic Podzoluvisols	PDi	162	1	180	1	175	1
Salic Fluvisols	FLs	n.a.	1	n.a.	1	n.a.	1	Stagnic Podzoluvisol	PDj	162	1	180	1	175	1
Thionic Fluvisols	FLt	n.a.	1	n.a.	1	n.a.	1	Calcaric Phaeozems	PHc	106	3	180	1	165	1
Umbric Fluvisols	FLu	n.a.	1	n.a.	1	n.a.	1	Gleyic Phaeozems	PHg	106	3	180	1	165	1
Geric Ferralsols	FRg	146	1	162	1	148	1	Haplic Phaeozems	PHh	106	3	180	1	165	1
Haplic Ferralsols	FRh	146	1	162	1	148	1	Stagnic Phaeozems	PHj	106	3	180	1	165	1
Plinthic Ferralsols	FRp	146	1	162	1	148	1	Luvic Phaeozems	PHI	162	1	180	1	175	1
Rhodic Ferralsols	FRr	146	1	162	1	148	1	Dystric Planosols	PLd	152	1	169	1	165	1
Humic Ferralsols	FRu	146	1	162	1	148	1	Eutric Planosols	PLe	152	1	169	1	165	1
Xanthic Ferralsols	FRx	146	1	162	1	148	1	Gelic Planosols	PLi	152	1	169	1	165	1
Andic Gleysols	GLa	n.a.	1	n.a.	1	n.a.	1	Mollic Planosols	PLm	152	1	169	1	165	1
Dystric Gleysols	GLd	n.a.	1	n.a.	1	n.a.	1	Umbric Planosols	PLu	152	1	169	1	165	1

**Soil moisture storage capacity classes derived for FAO soil units of Revised Legend '90
(continued)**

FAO Legend '90 Soil Unit	SLU	coarse		medium		fine		FAO Legend '90 Soil Unit	SLU	coarse		medium		fine	
		mm	CL	mm	CL	mm	CL			mm	CL	mm	CL		
Albic Plinthosols	PTa	95	3	162	1	148	1	Gleyic Solonchaks	SCg	106	3	180	1	165	1
Dystric Plinthosols	PTd	95	3	162	1	148	1	Haplic Solonchaks	SCh	106	3	180	1	165	1
Eutric Plinthosols	PTe	95	3	162	1	148	1	Gelic Solonchaks	SCi	106	3	180	1	165	1
Humic Plinthosols	PTu	95	3	162	1	148	1	Calcic Solonchaks	SCK	106	3	180	1	165	1
Cambic Podzols	PZb	106	3	180	1	165	1	Mollic Solonchaks	SCm	106	3	180	1	165	1
Carbic Podzols	PZc	106	3	180	1	165	1	Sodic Solonchaks	SCn	106	3	180	1	165	1
Ferric Podzols	PZf	106	3	180	1	165	1	Gypsic Solonchaks	SCy	106	3	180	1	165	1
Gleyic Podzols	PZg	106	3	180	1	165	1	Gleyic Solonetz	SNg	106	3	180	1	165	1
Haplic Podzols	PZh	106	3	180	1	165	1	Haplic Solonetz	SNh	106	3	180	1	165	1
Gelic Podzols	PZi	106	3	180	1	165	1	Stagnic Solonetz	SNj	106	3	180	1	165	1
Calcaric Regosols	RGc	106	3	180	1	165	1	Calcic Solonetz	SNk	106	3	180	1	165	1
Dystric Regosols	RGd	106	3	180	1	165	1	Mollic Solonetz	SNm	106	3	180	1	165	1
Eutric Regosols	RGe	106	3	180	1	165	1	Gypsic Solonetz	SNy	106	3	180	1	165	1
Gelic Regosols	RGi	106	3	180	1	165	1	Dystric Vertisols	VRd	135	2	135	2	135	2
Umbric Regosols	RGu	106	3	180	1	165	1	Eutric Vertisols	VRe	135	2	135	2	135	2
Gypsic Regosols	RGy	106	3	180	1	165	1	Calcic Vertisols	VRk	135	2	135	2	135	2
								Gypsic Vertisols	VRy	135	2	135	2	135	2

APPENDIX XIV

**Table 1 Terrain slope ratings for rain-fed conditions (Fm: 1300-1800)
High Inputs**

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100			50	50				100			100			100
Annual 2	100			100			100			50	50				100			100			100
Wetland Rice	100			50	50			50	50			100			100			100			100
Sugarcane	100			100			50	50			50	50			100			100			100
Olive	100			100			100				100				100			100			100
Perennials	100			100			100				100				100			100			100
Pasture	100			100			100				100			50	50			100			100
Forage Legumes	100			100			100			50	50				100			100			100

Intermediate Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100			50	50			50	50			100			100
Annual 2	100			100			100			50	50			50	50			100			100
Wetland Rice	100			50	50			100				100			100			100			100
Sugarcane	100			100			50	50			50	50			100			100			100
Olive	100			100			100			50	50			50	50			100			100
Perennials	100			100			100				100			25	75			100			100
Pasture	100			100			100			100			50	50			25	75			100
Forage Legumes	100			100			100			100			25	50	25			100			100

Low Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100			100				50	50			100			100
Annual 2	100			100			100			50	50			50	50			100			100
Wetland Rice	100			50	50			100				100			100			100			100
Sugarcane	100			100			50	50			50	50			100			100			100
Olive	100			100			100			50	50			50	50			100			100
Perennials	100			100			100				100			25	75			100			100
Pasture	100			100			100			100			50	50			25	75			100
Forage Legumes	100			100			100			100			25	50	25			100			100

Modified Fournier index: $Fm = 12 \sum_{i=1}^{12} \frac{P_i^2}{P_{ann}}$ where: p_i = rainfall of month i and P_{ann} = annual rainfall total

Table 2 Terrain slope ratings for rain-fed conditions (Fm: 1800-2200)

High Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
Crop Groups	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100			25	50	25			100			100			100
Annual 2	100			100			100			25	50	25			100			100			100
Wetland Rice	100			50	50			50	50			100			100			100			100
Sugarcane	100			100			50	50			25	75			100			100			100
Olive	100			100			100				50	50			100			100			100
Perennials	100			100			100				50	50			100			100			100
Pasture	100			100			100			100				25	75			100			100
Forage Legumes	100			100			100			25	50	25			100			100			100

Intermediate Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
Crop Groups	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100			25	50	25			100			100			100
Annual 2	100			100			100			25	50	25			100			100			100
Wetland Rice	100			50	50			100				100			100			100			100
Sugarcane	100			100			50	50			25	75			100			100			100
Olive	100			100			100			25	50	25			100			100			100
Perennials	100			100			100				50	50			100			100			100
Pasture	100			100			100			100			50	50			25	75			100
Forage Legumes	100			100			100			100				50	50			100			100

Low Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
Crop Groups	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100			50	50				100			100			100
Annual 2	100			100			100			25	50	25			100			100			100
Wetland Rice	100			50	50			100				100			100			100			100
Sugarcane	100			100			50	50			25	75			100			100			100
Olive	100			100			100			25	50	25			100			100			100
Perennials	100			100			100				50	50			100			100			100
Pasture	100			100			100			100			50	50			25	75			100
Forage Legumes	100			100			100			50	50			50	50			100			100

Modified Fournier index: $Fm = 12 \sum_{i=1}^{12} \frac{p_i^2}{P_{ann}}$ where: p_i = rainfall of month i and P_{ann} = annual rainfall total

Table 3 Terrain slope ratings for rain-fed conditions (Fm: 2200-2500)

High Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
Crop Groups	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100				50	50			100			100			100
Annual 2	100			100			100				50	50			100			100			100
Wetland Rice	100			50	50			50	50			100			100			100			100
Sugarcane	100			100			50	50				100			100			100			100
Olive	100			100			100					100			100			100			100
Perennials	100			100			100					100			100			100			100
Pasture	100			100			100			100					100			100			100
Forage Legumes	100			100			100				50	50			100			100			100

Intermediate Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
Crop Groups	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100				50	50			100			100			100
Annual 2	100			100			100				50	50			100			100			100
Wetland Rice	100			50	50			100				100			100			100			100
Sugarcane	100			100			50	50				100			100			100			100
Olive	100			100			100				50	50			100			100			100
Perennials	100			100			100					100			100			100			100
Pasture	100			100			100			100			25	50	25			100			100
Forage Legumes	100			100			100				100			25	75			100			100

Low Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
Crop Groups	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100				100				100			100			100
Annual 2	100			100			100				50	50			100			100			100
Wetland Rice	100			50	50			100				100			100			100			100
Sugarcane	100			100			50	50				100			100			100			100
Olive	100			100			100				50	50			100			100			100
Perennials	100			100			100					100		50	100			100			100
Pasture	100			100			100			100			25	50	25			100			100
Forage Legumes	100			100			100				100			25	75			100			100

Modified Fournier index: $Fm = 12 \sum_{i=1}^{12} \frac{p_i^2}{P_{ann}}$ where: p_i = rainfall of month i and P_{ann} = annual rainfall total

Table 4 Terrain slope ratings for rain-fed conditions (Fm: 2500-2700)

High Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
Crop Groups	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100				25	75			100			100			100
Annual 2	100			100			100				25	75			100			100			100
Wetland Rice	100			50	50			50	50			100			100			100			100
Sugarcane	100			100			50	50				100			100			100			100
Olive	100			100			100					100			100			100			100
Perennials	100			100			100					100			100			100			100
Pasture	100			100			100			50	50				100			100			100
Forage Legumes	100			100			100				25	75			100			100			100

Intermediate Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
Crop Groups	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100				25	75			100			100			100
Annual 2	100			100			100				25	75			100			100			100
Wetland Rice	100			50	50			100				100			100			100			100
Sugarcane	100			100			50	50				100			100			100			100
Olive	100			100			100				25	75			100			100			100
Perennials	100			100			100					100			100			100			100
Pasture	100			100			100			100				25	75			100			100
Forage Legumes	100			100			100				50	50			100			100			100

Low Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
Crop Groups	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			100				50	50			100			100			100
Annual 2	100			100			100				25	75			100			100			100
Wetland Rice	100			50	50			100				100			100			100			100
Sugarcane	100			100			50	50				100			100			100			100
Olive	100			100			100				25	75			100			100			100
Perennials	100			100			100					100			100			100			100
Pasture	100			100			100			100				25	75			100			100
Forage Legumes	100			100			100				50	50			100			100			100

Modified Fournier index: $Fm = 12 \sum_{i=1}^{12} \frac{P_i^2}{P_{ann}}$ where: p_i = rainfall of month i and P_{ann} = annual rainfall total

Table 5 Terrain slope ratings for rain-fed conditions (Fm > 2700)

High Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			50	50				100			100			100			100
Annual 2	100			100			50	50				100			100			100			100
Wetland Rice	100			50	50			25	75			100			100			100			100
Sugarcane	100			100			25	50	25			100			100			100			100
Olive	100			100			50	50				100			100			100			100
Perennials	100			100			50	50				100			100			100			100
Pasture	100			100			100				50	50			100			100			100
Forage Legumes	100			100			50	50				100			100			100			100

Intermediate Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			50	50			25	75			100			100			100
Annual 2	100			100			50	50			25	75			100			100			100
Wetland Rice	100			50	50			50	50			100			100			100			100
Sugarcane	100			100			25	50	25			100			100			100			100
Olive	100			100			50	50			25	75			100			100			100
Perennials	100			100			50	50				100			100			100			100
Pasture	100			100			100				100			50	50			100			100
Forage Legumes	100			100			50	50			50	50			100			100			100

Low Inputs

Slope Gradient Classes	0-2 %			2-5%			5-8%			8-16%			16-30%			30-45%			> 45%		
	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N	S1	S2	N
Annual 1	100			100			50	50			50	50			100			100			100
Annual 2	100			100			50	50			25	75			100			100			100
Wetland Rice	100			50	50			50	50			100			100			100			100
Sugarcane	100			100			25	50	25			100			100			100			100
Olive	100			100			50	50			25	75			100			100			100
Perennials	100			100			50	50				100			100			100			100
Pasture	100			100			100				100			50	50			100			100
Forage Legumes	100			100			50	50			50	50			100			100			100

Crop Groups: Annual 1: wheat, barley, rye
 Annual 2: (maize, sorghum, pearl millet, foxtail millet, white potato, sweet potato, phaseolus bean, chickpea, cowpea, soybean and groundnut, sunflower, cotton, sugar beet, rape
 Perennials: cassava, oil palm, banana, plantain

APPENDIX XV

Plates with selected results of the Global AEZ assessment

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Plate 1. Average annual precipitation

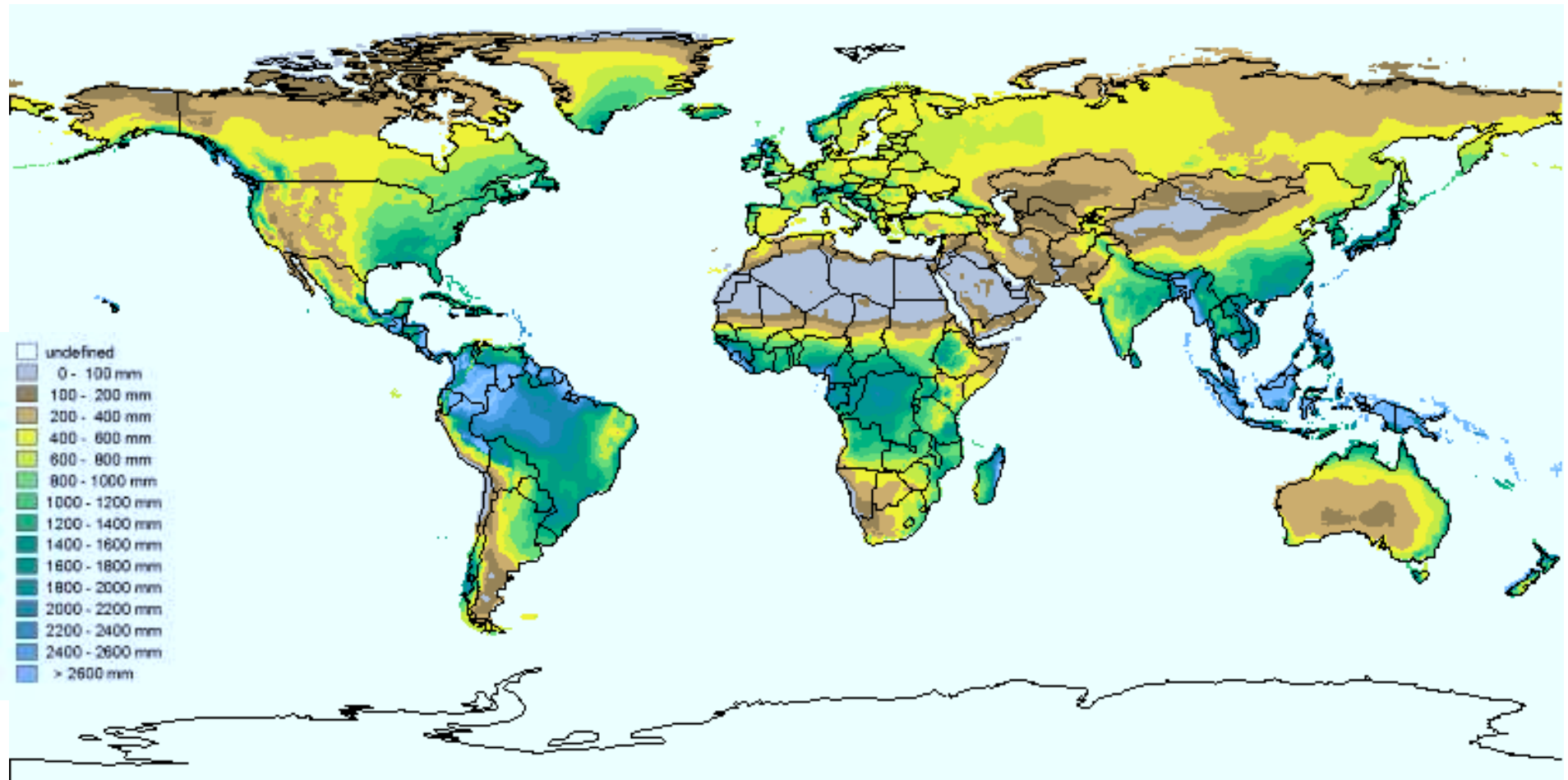


Plate 2. Average annual reference evapotranspiration (Penman-Monteith)

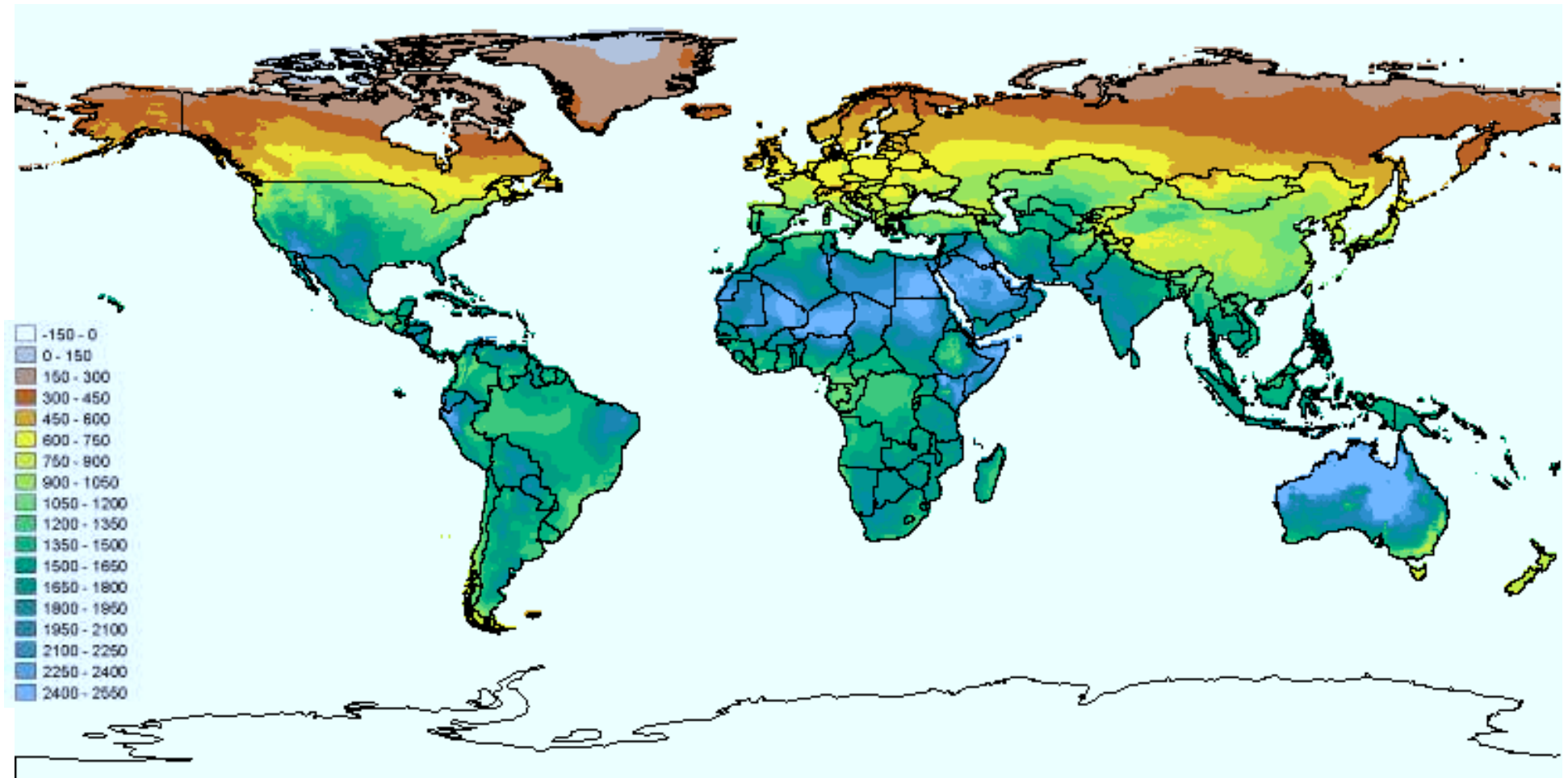


Plate 3. Thermal climates

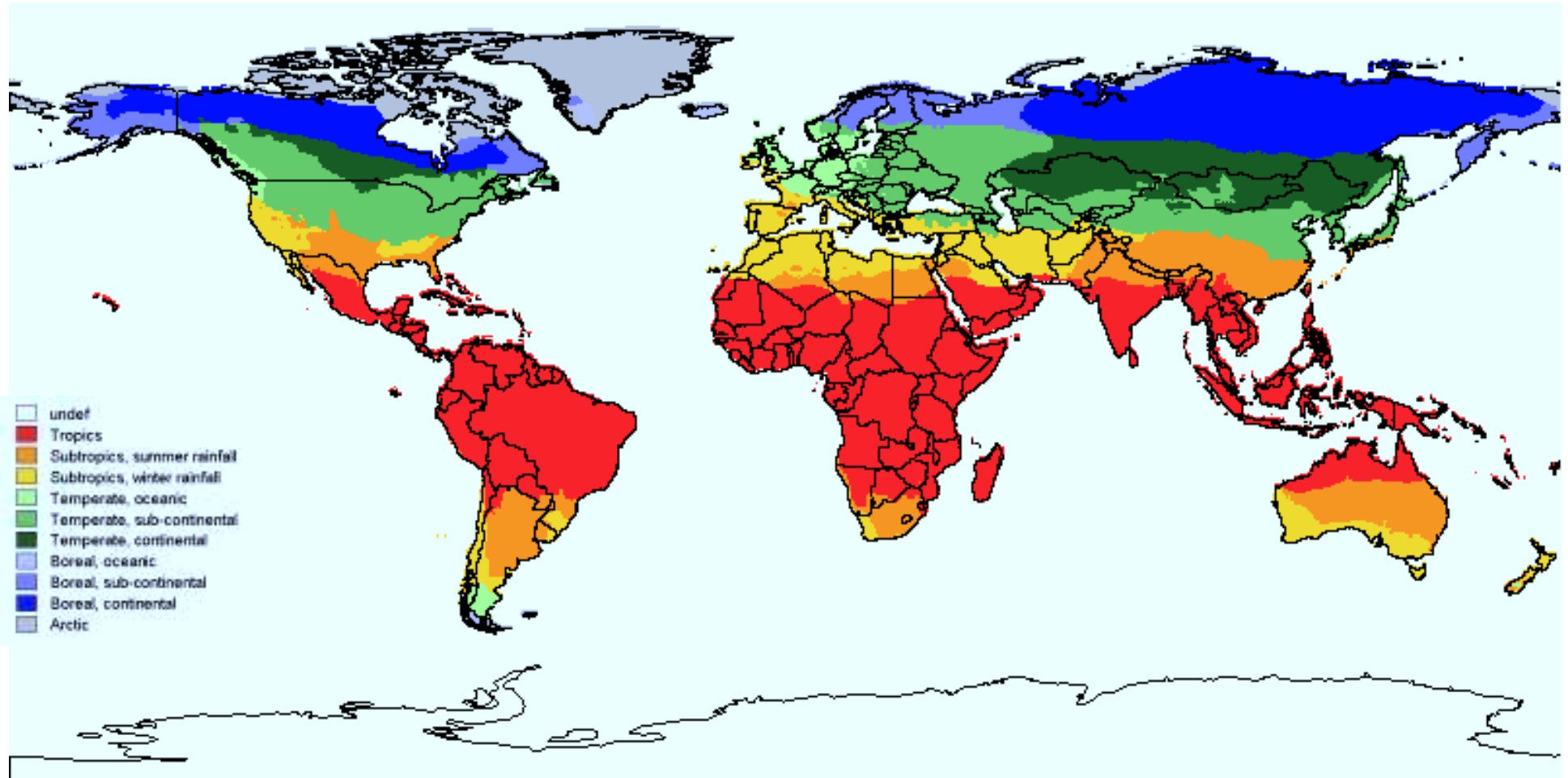


Plate 4. Temperature growing periods ($LGP_{t=5}$)

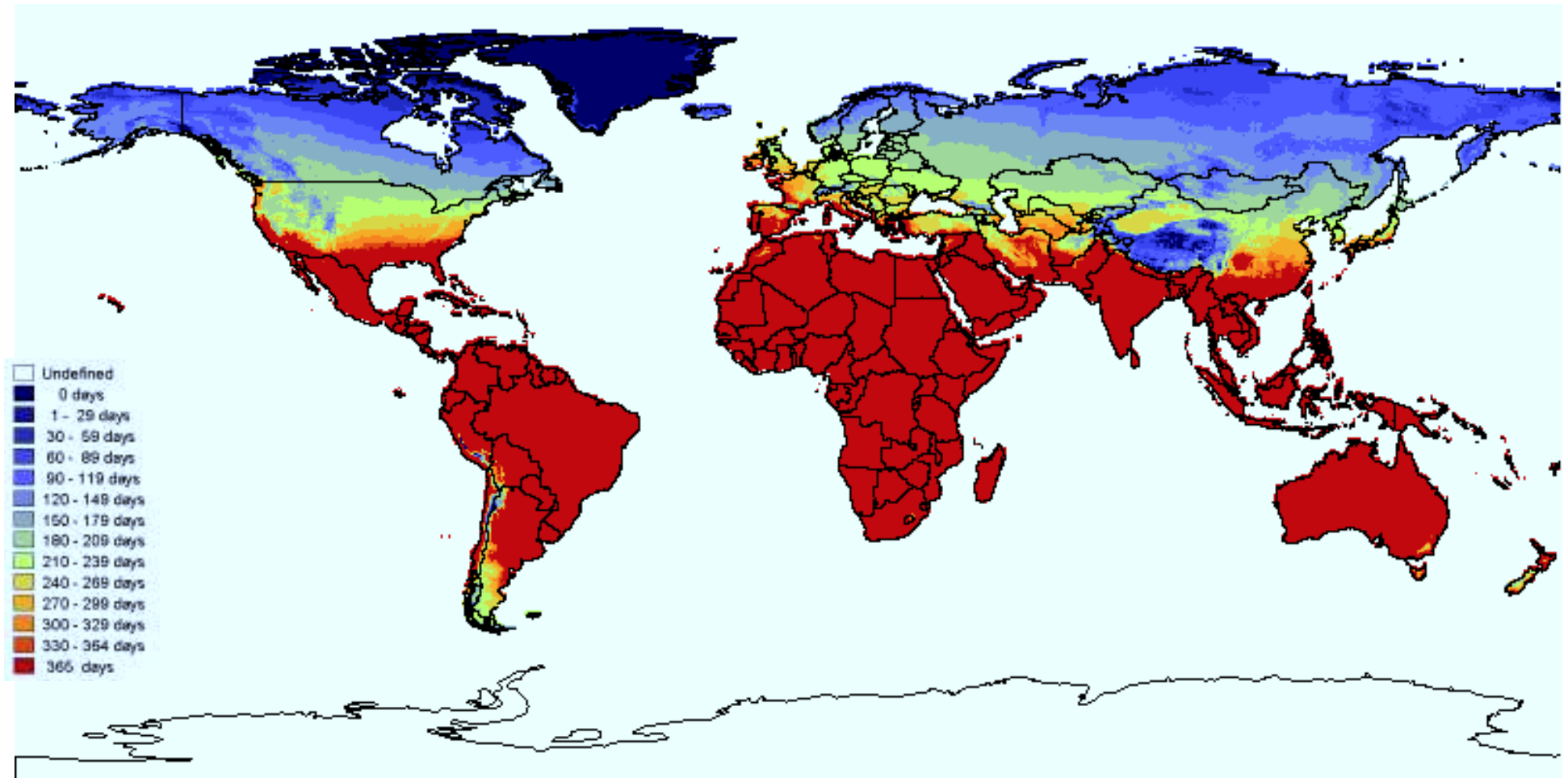


Plate 5. Frost-free periods ($LGP_{t=10}$)

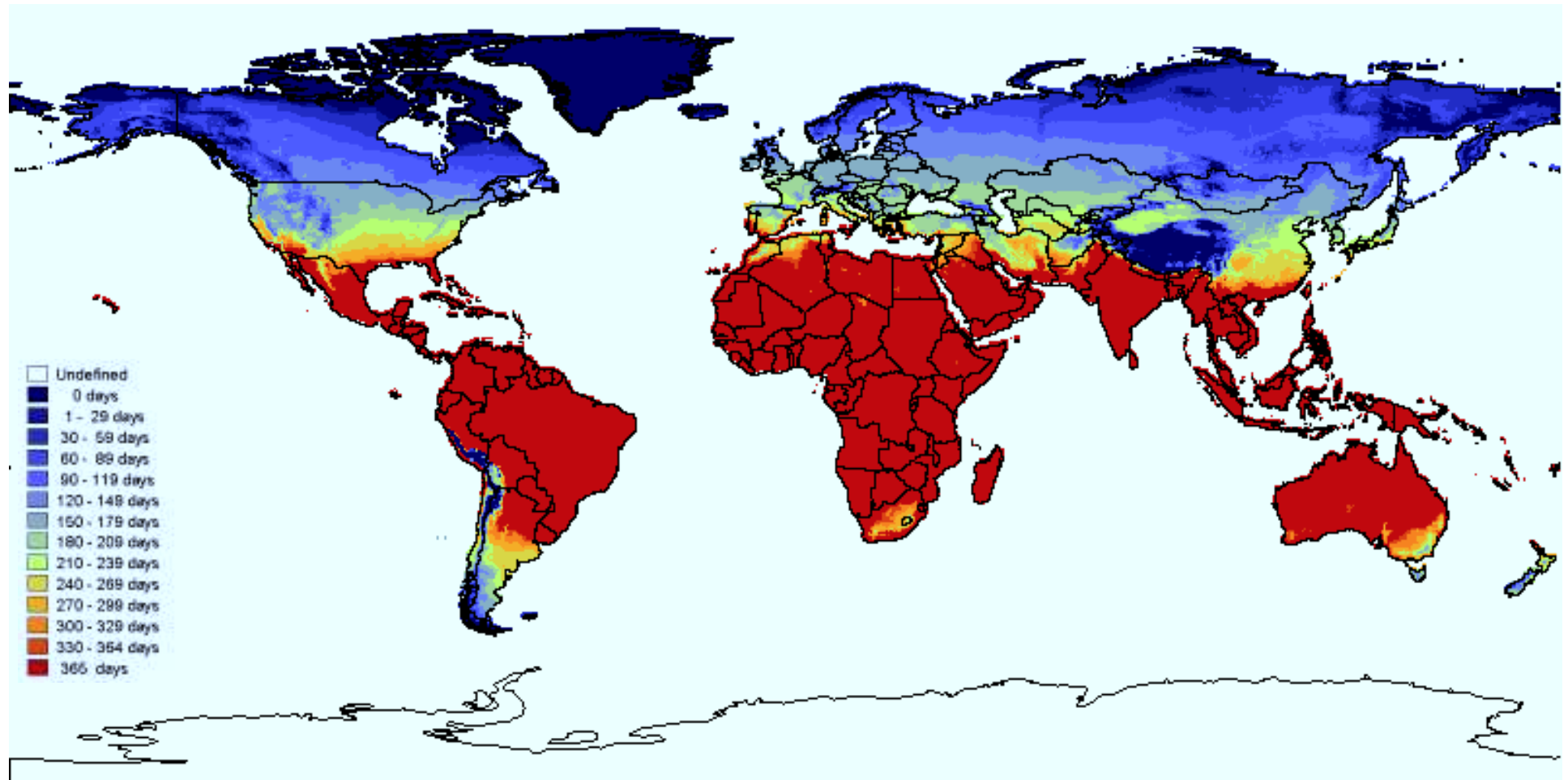


Plate 6. Accumulated temperatures ($T_{\text{mean}} > 0^{\circ}\text{C}$)

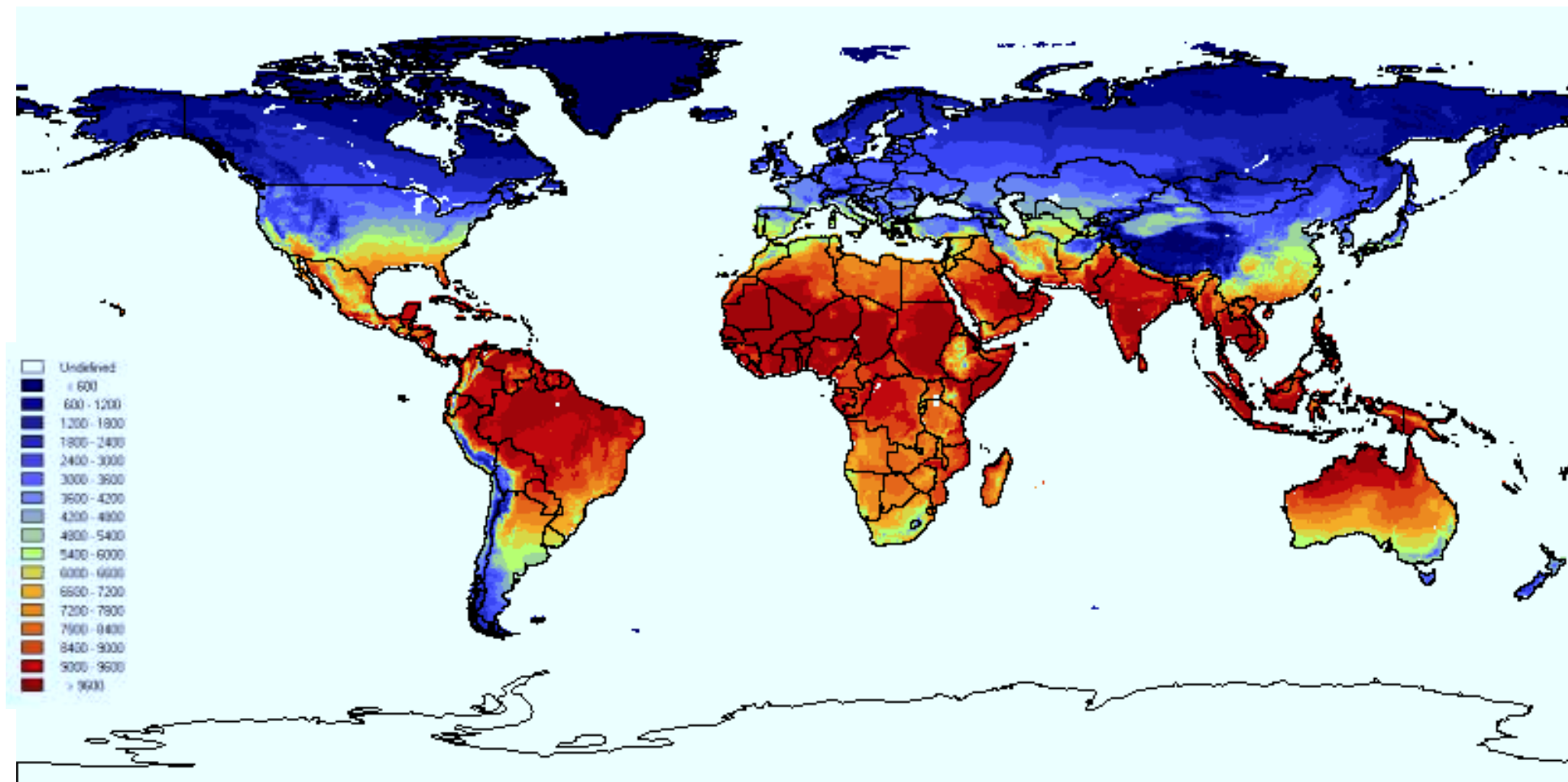


Plate 7. Total length of growing periods

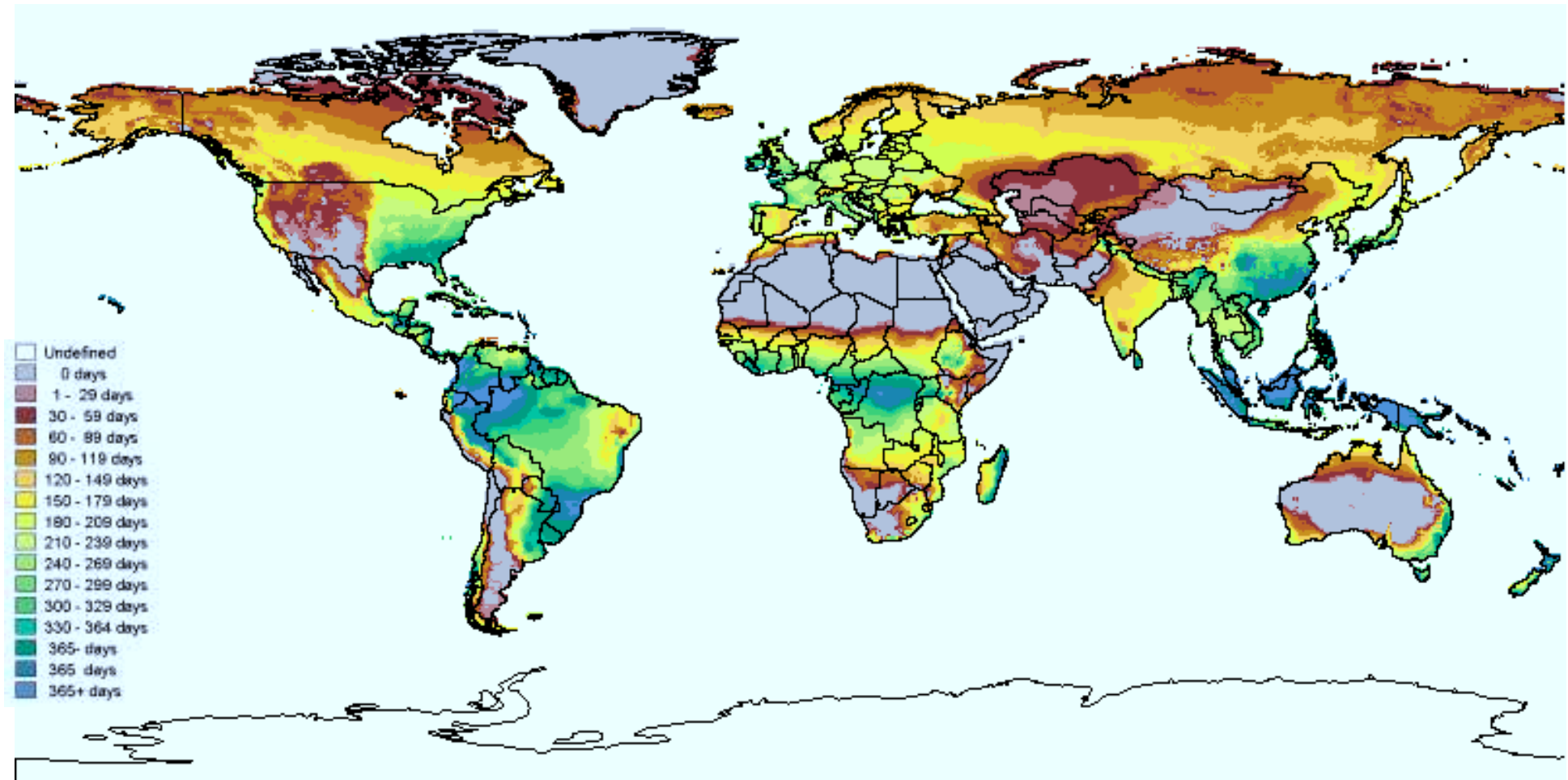


Plate 8. Growing period patterns

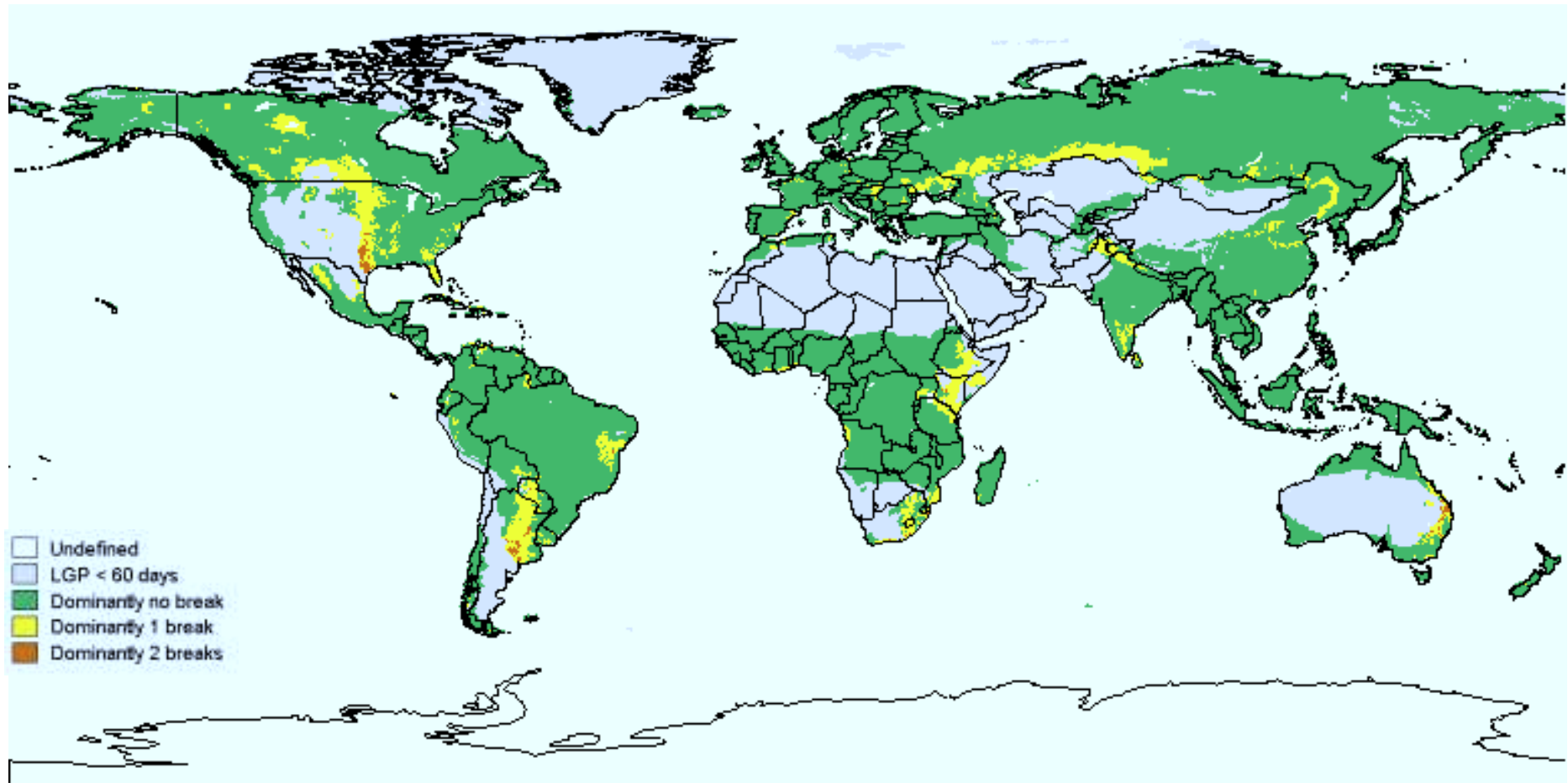


Plate 9. Median of terrain slopes derived from GTOPO30

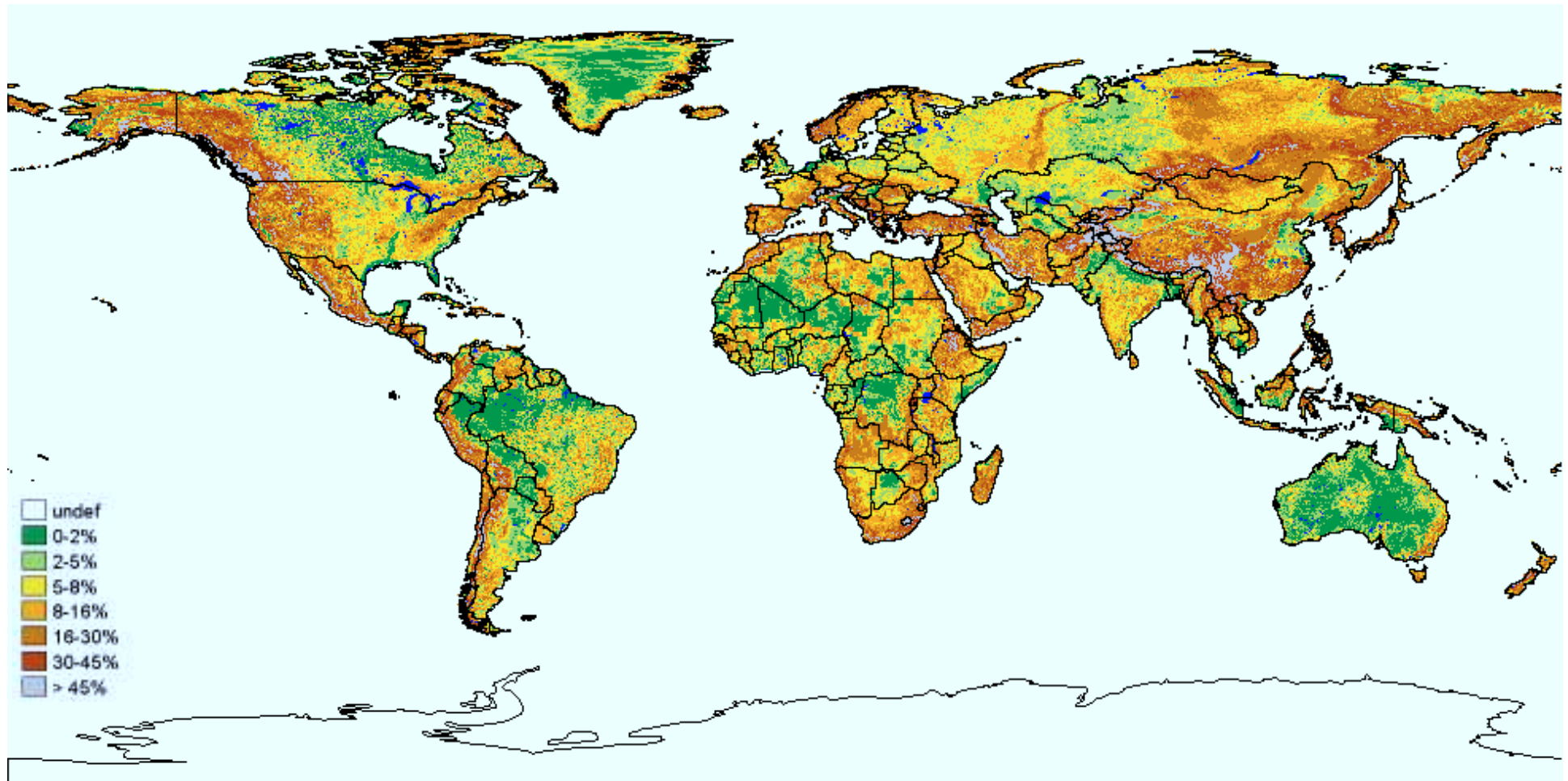


Plate 10. Temperature and radiation limited yield for rain-fed wheat (high inputs)

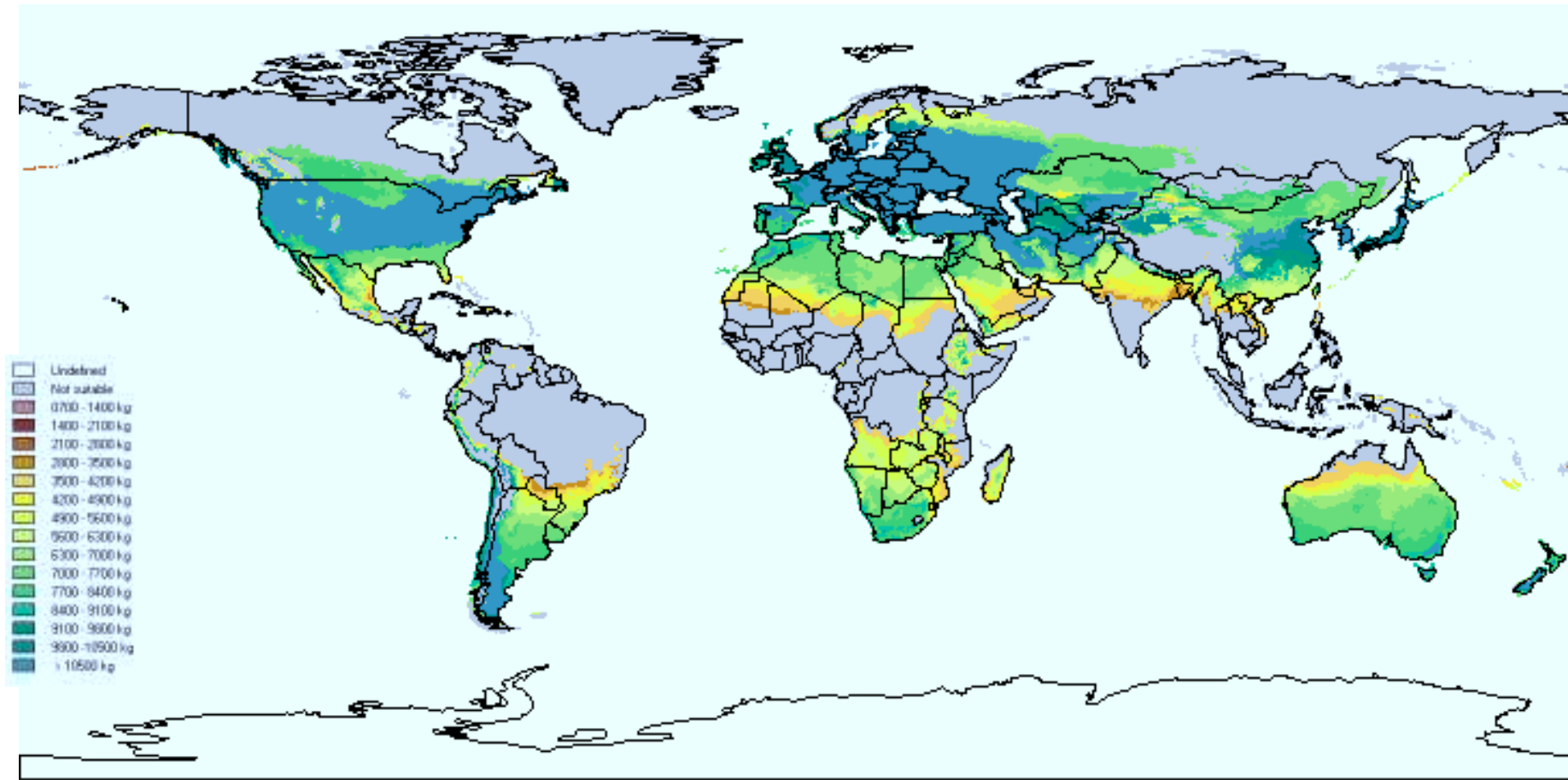


Plate 11. Agro-climatic suitability for rain-fed wheat (high inputs)

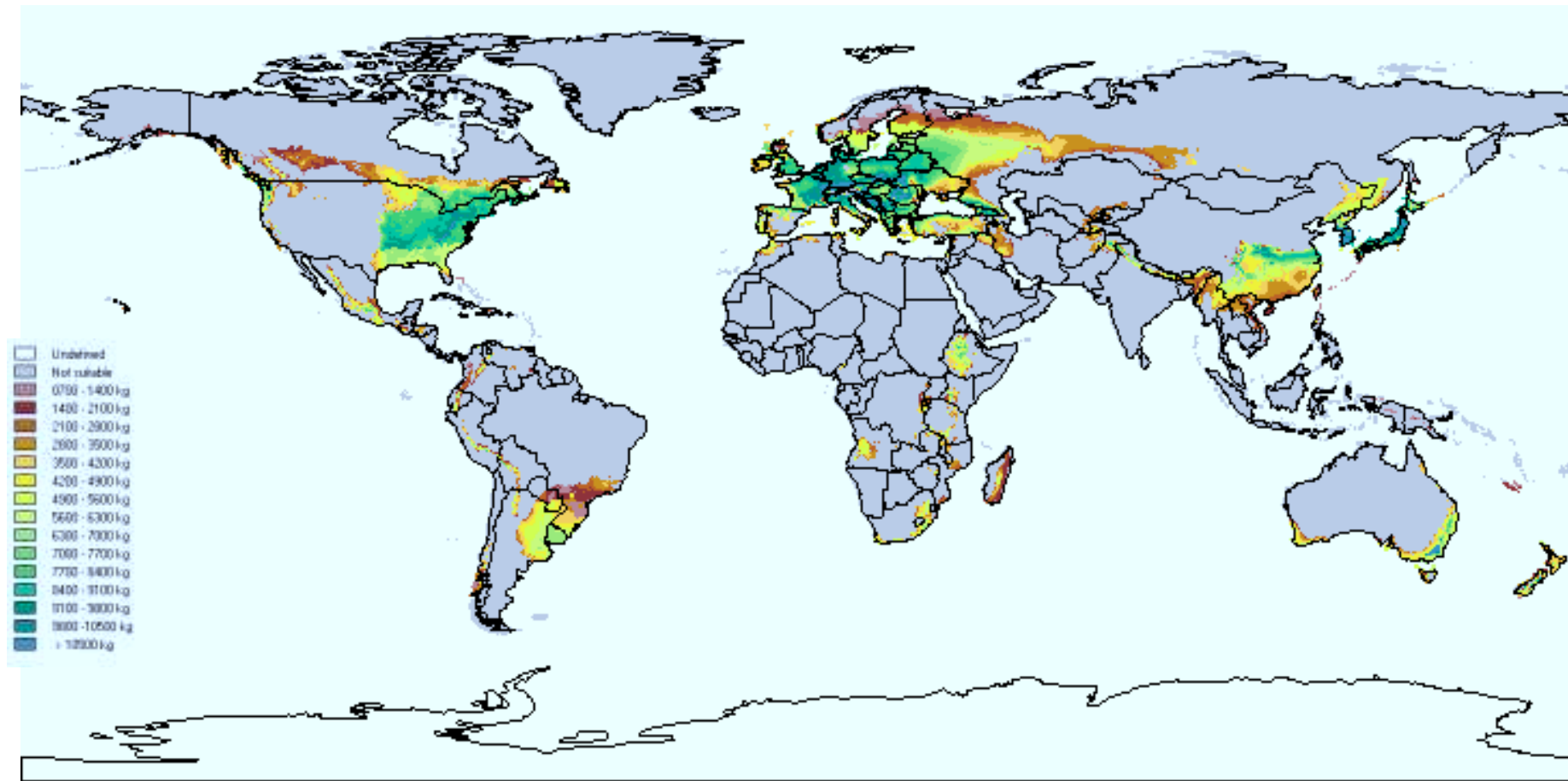


Plate 12. Agro-climatic suitability for rain-fed and irrigated wheat (high inputs)

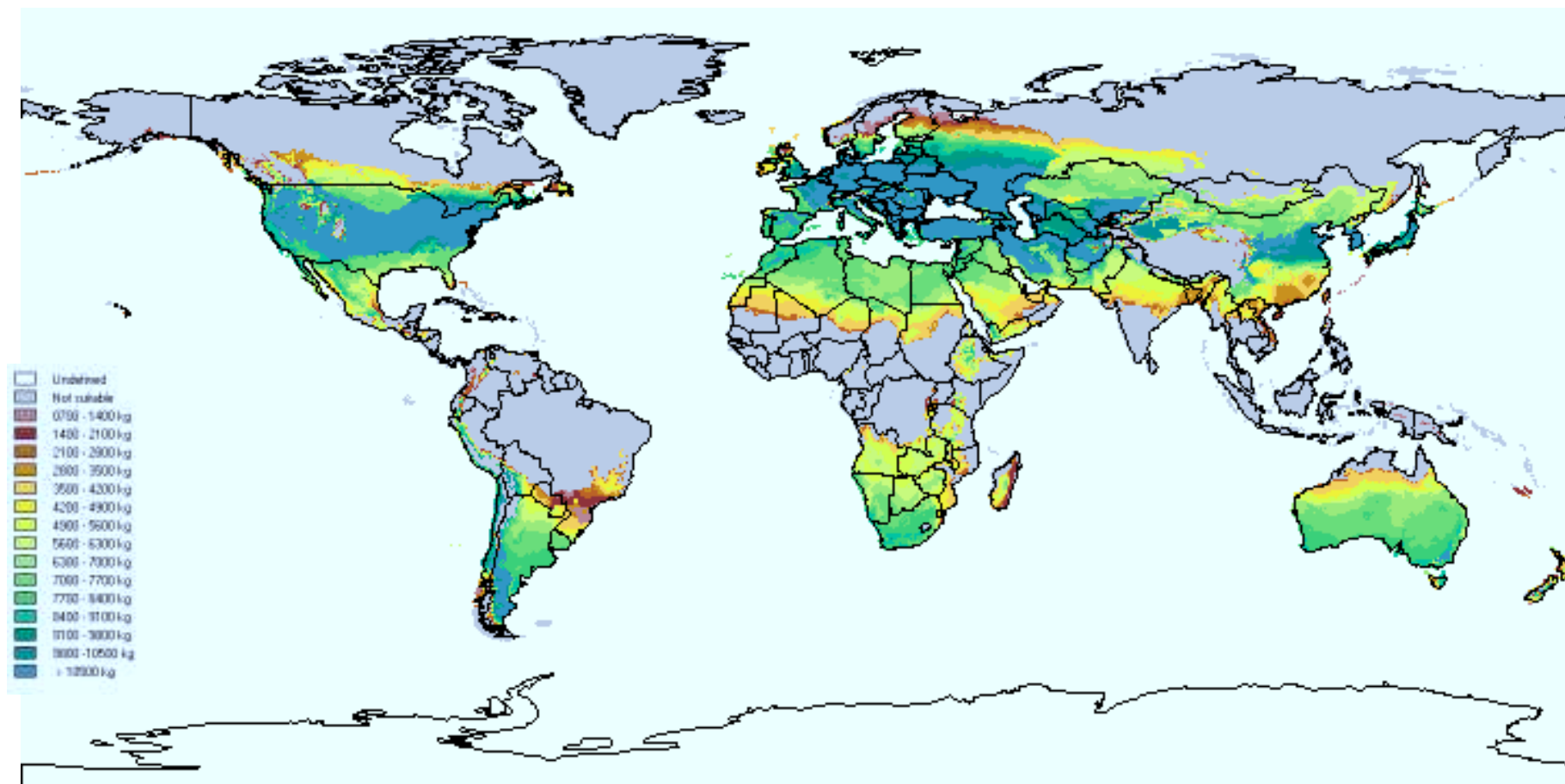


Plate 13. Multiple cropping zones - rain-fed conditions

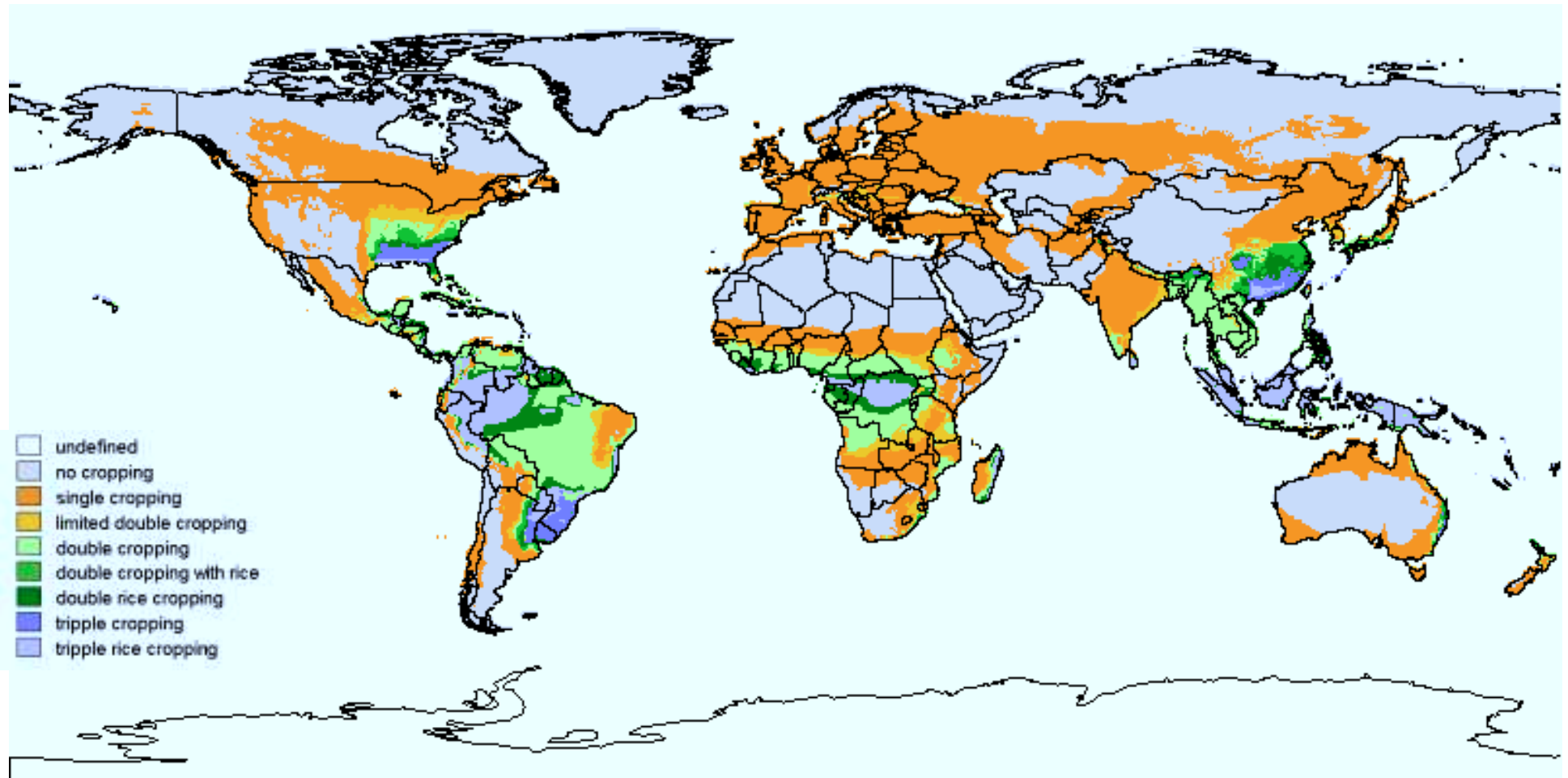


Plate 14. Number of growing period days

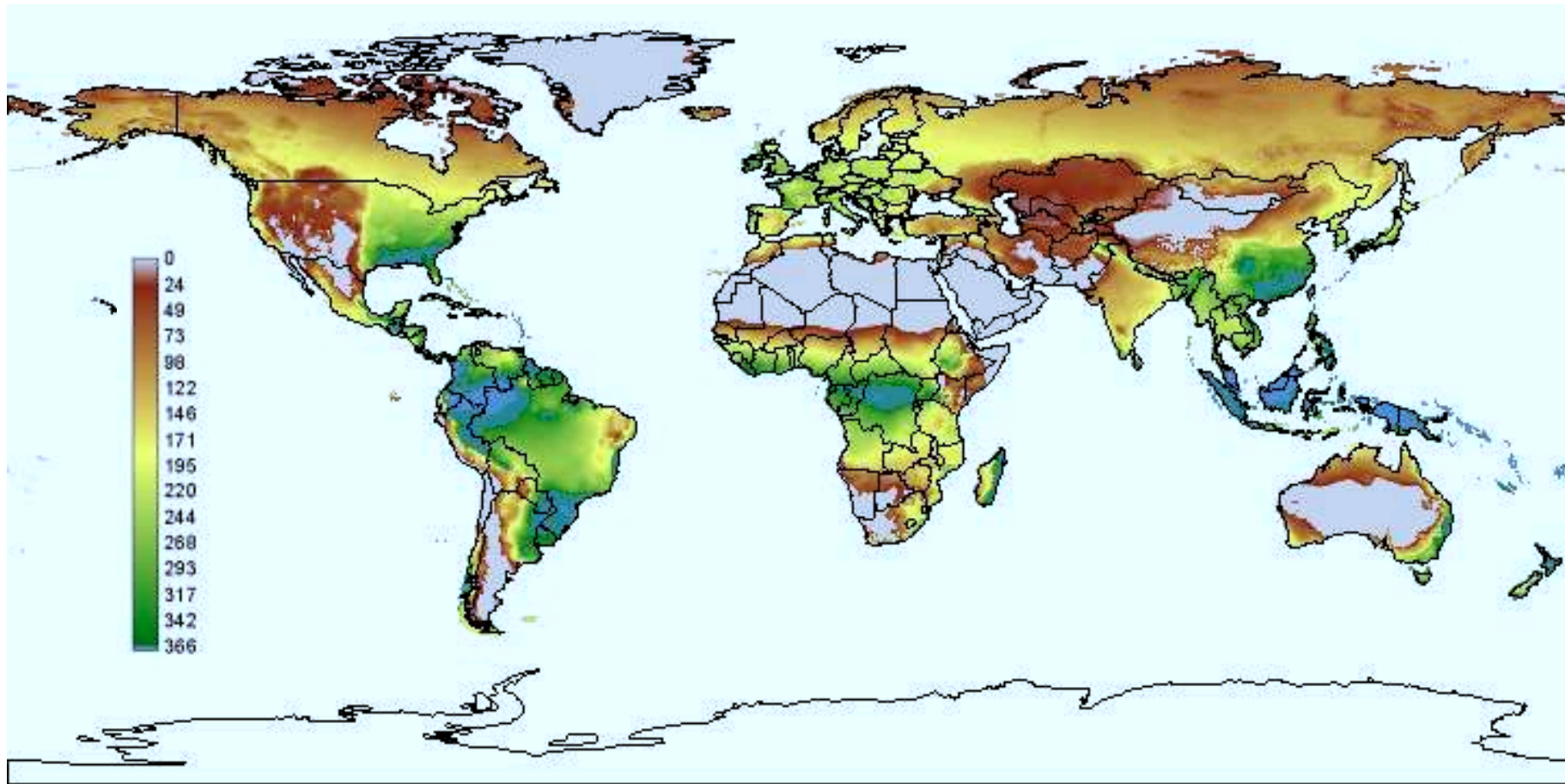


Plate 15. Temperature and radiation limited yield for 120 day rain-fed grain maize (high inputs)

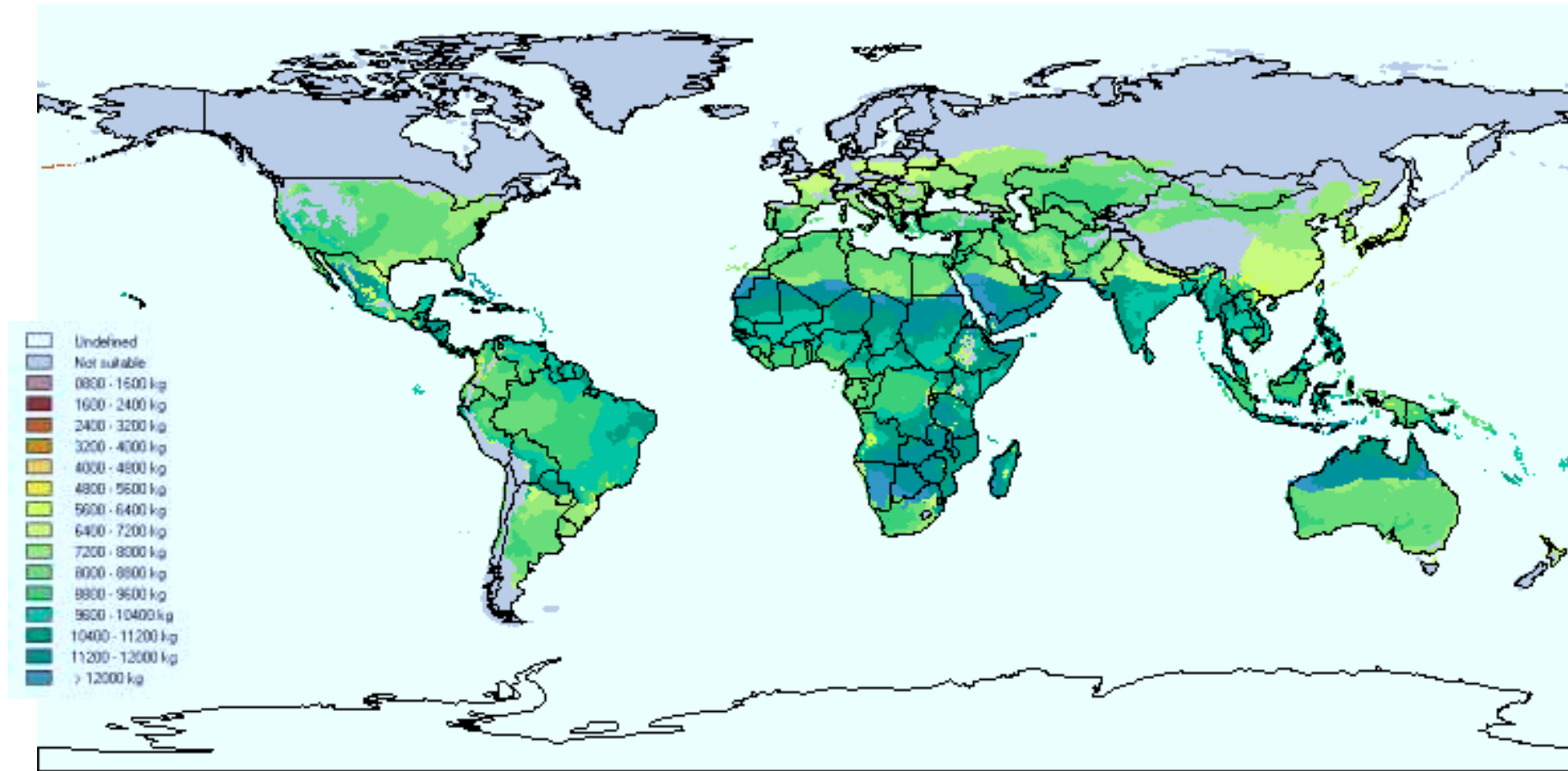


Plate 16. Temperature, radiation and water limited yield for 120 day rain-fed grain maize (high inputs)

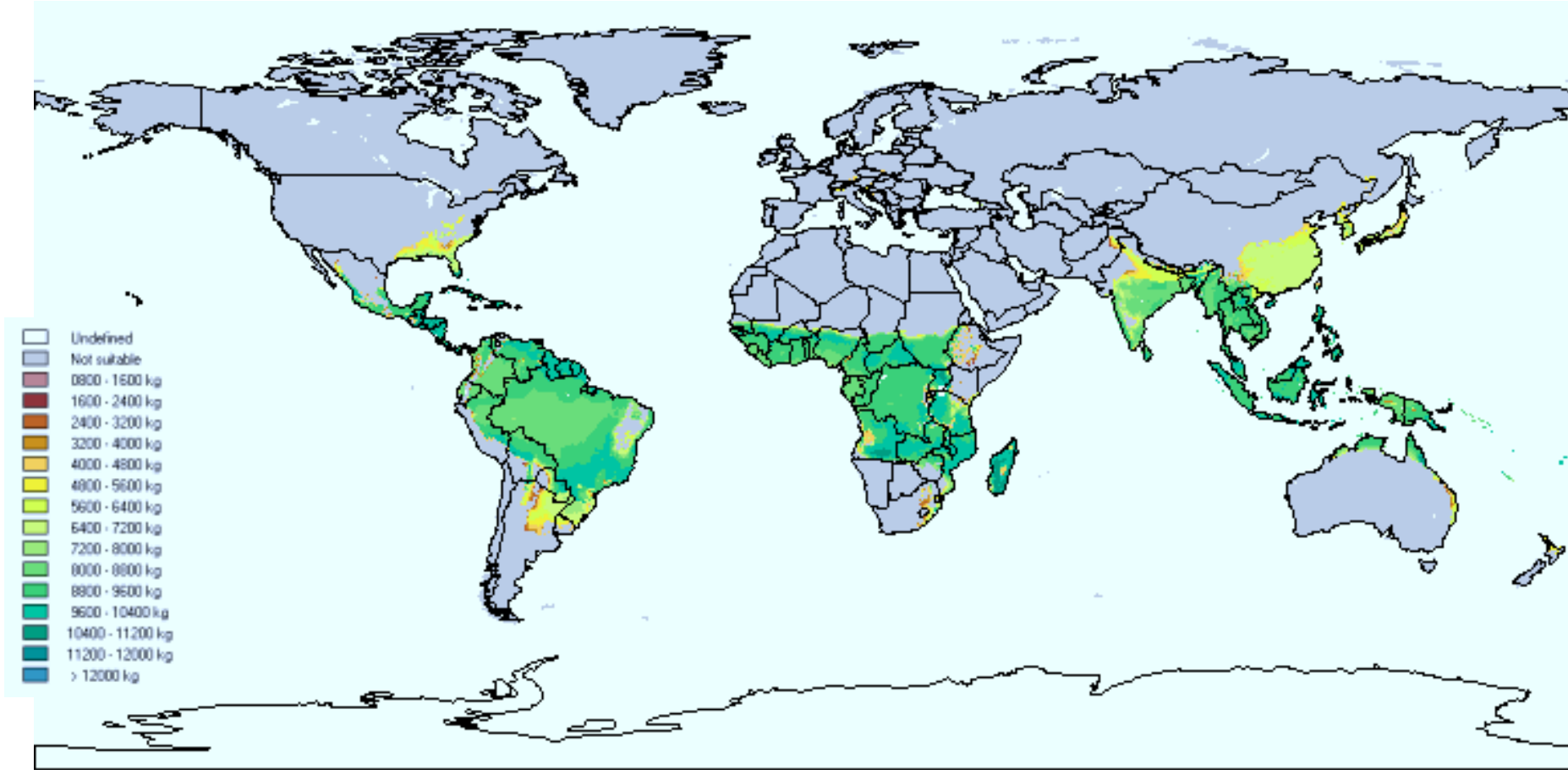


Plate 17. Agro-climatically attainable yield for 120 day rain-fed grain maize (high inputs)

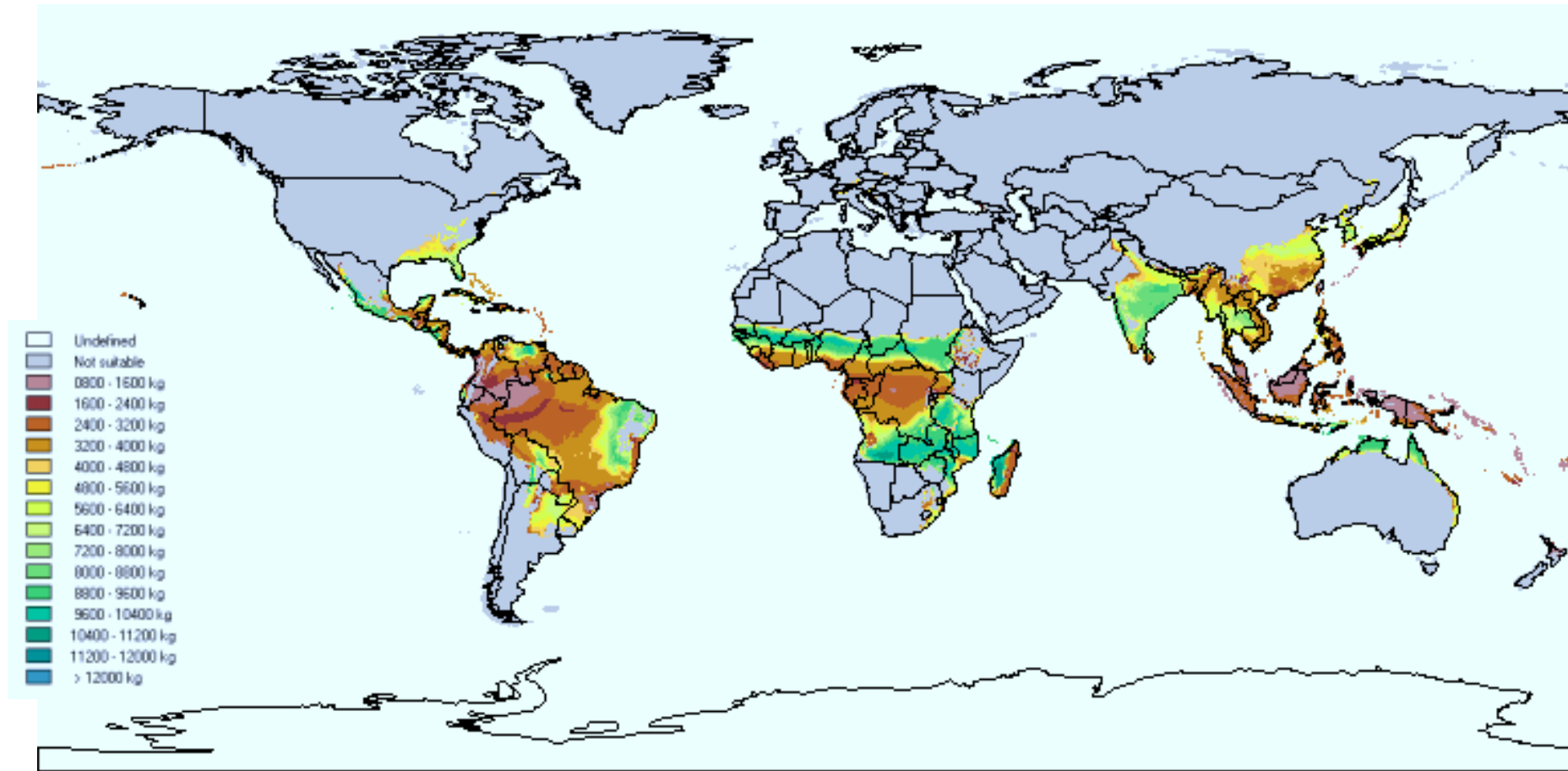


Plate 18. Expected grid-cell output per hectare for 120 day rain-fed grain maize (high inputs)

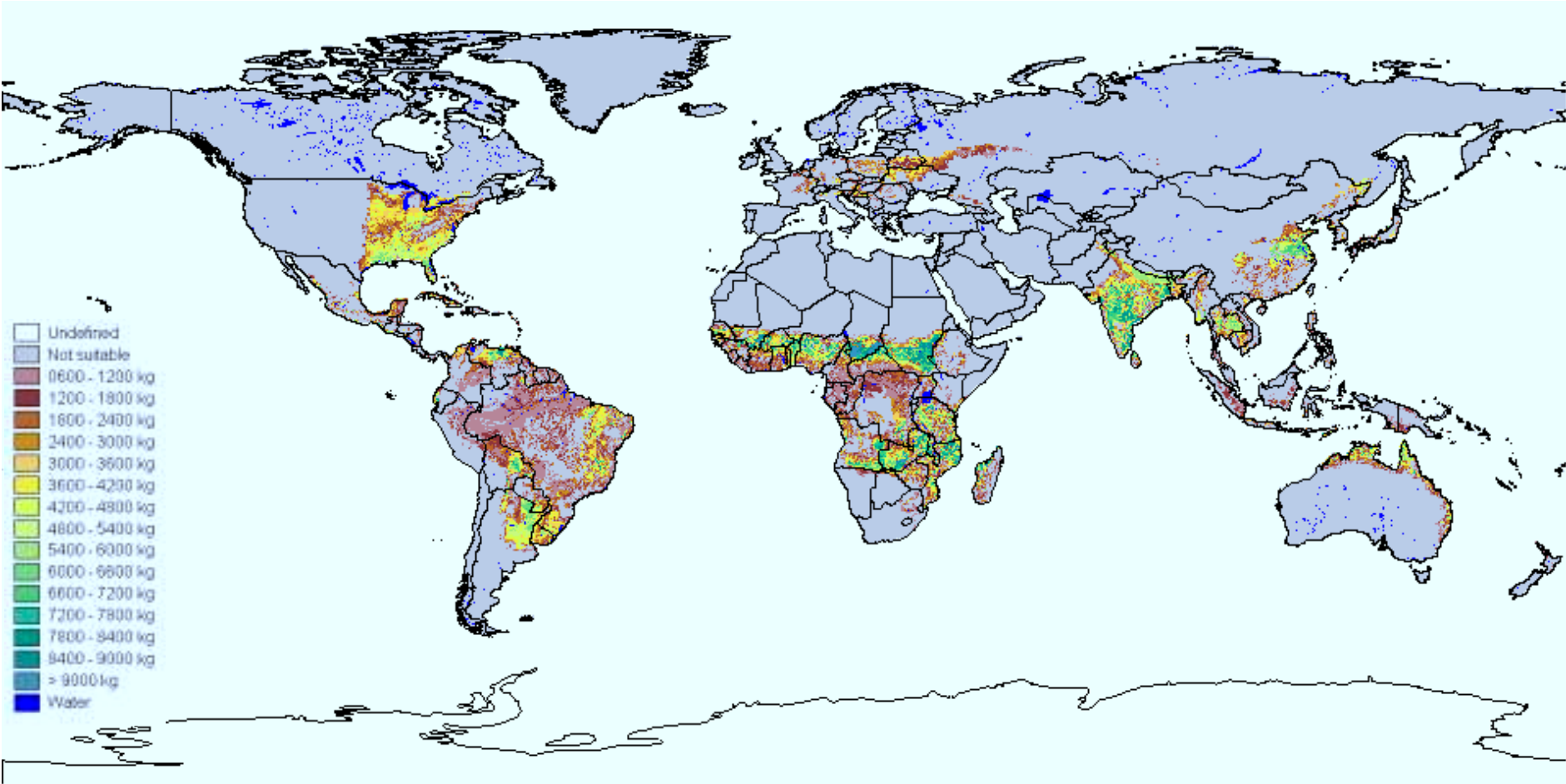


Plate 19. Expected grid-cell output per hectare across all 13 rain-fed grain-maize types (high inputs)

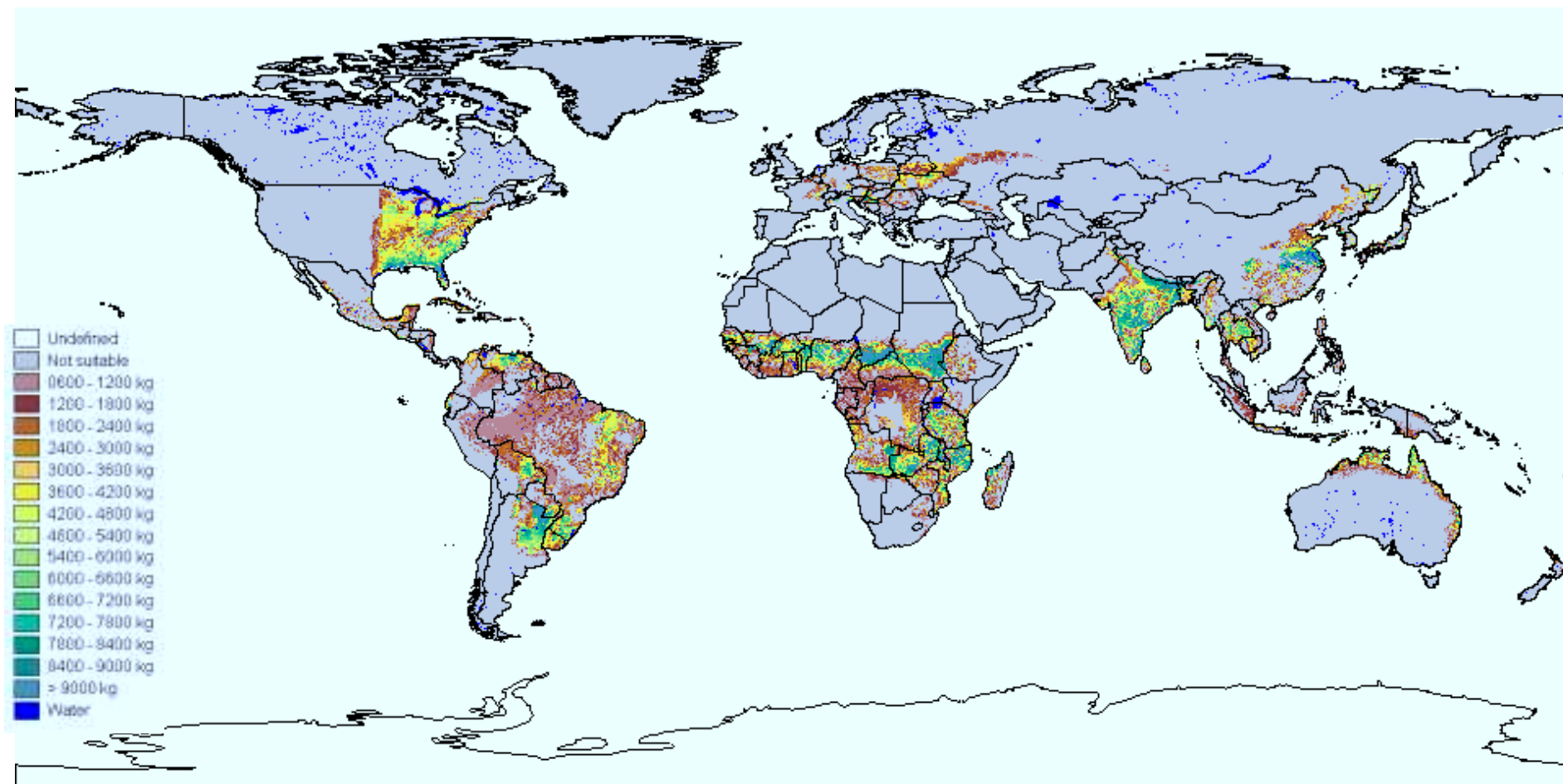


Plate 20. Climate constraints

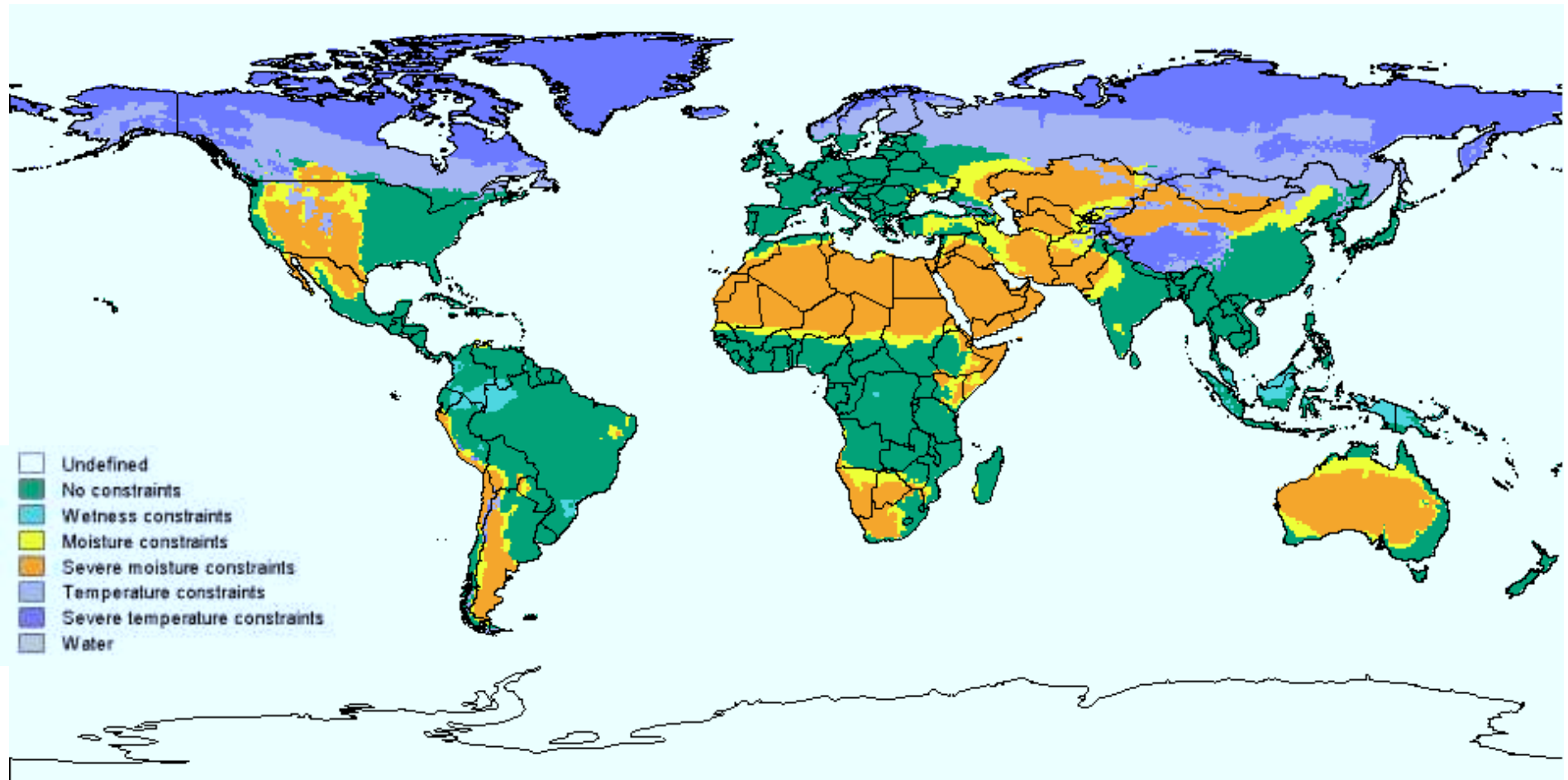


Plate 21. Soil depth constraints

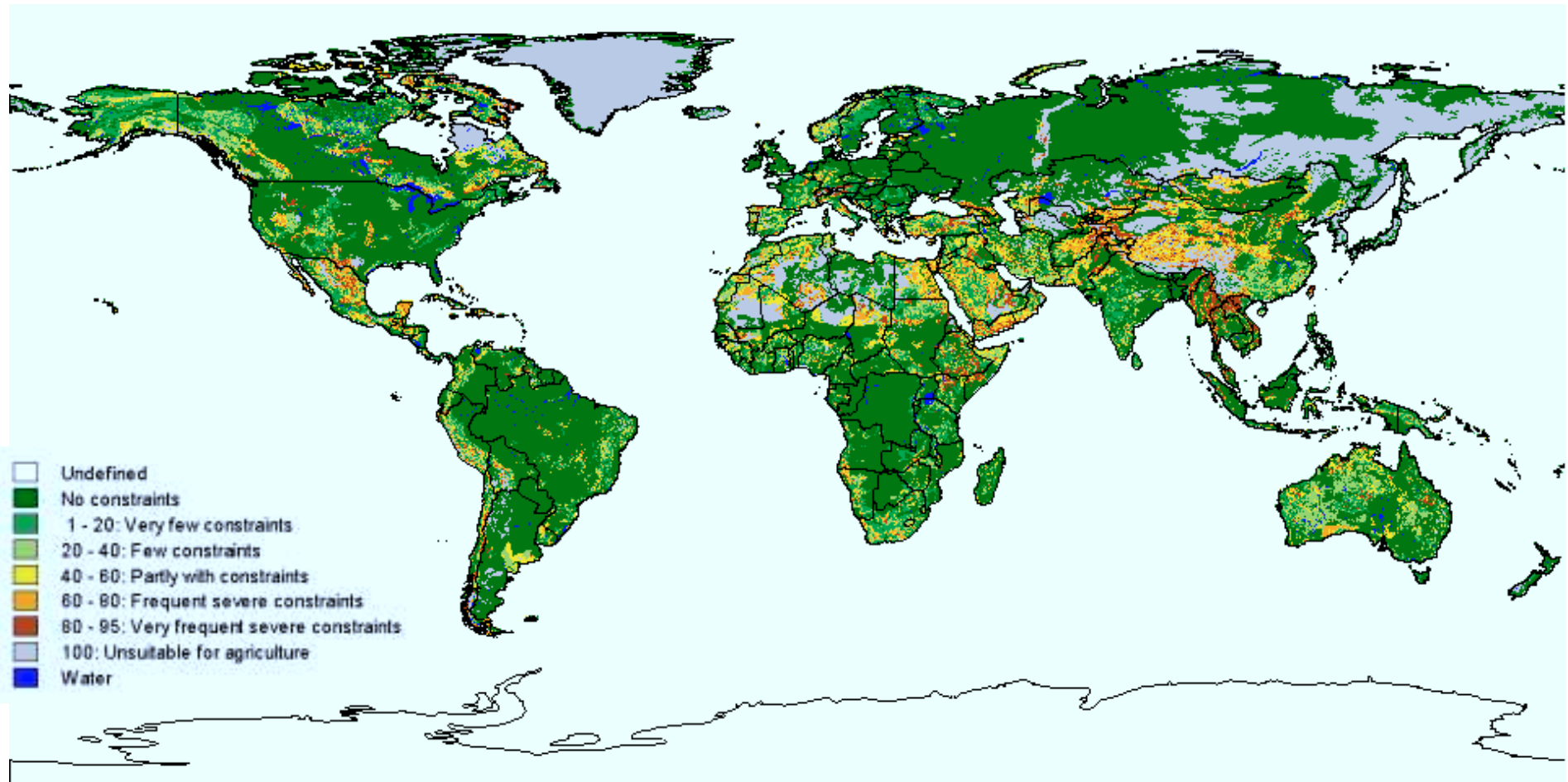


Plate 22. Soil fertility constraints

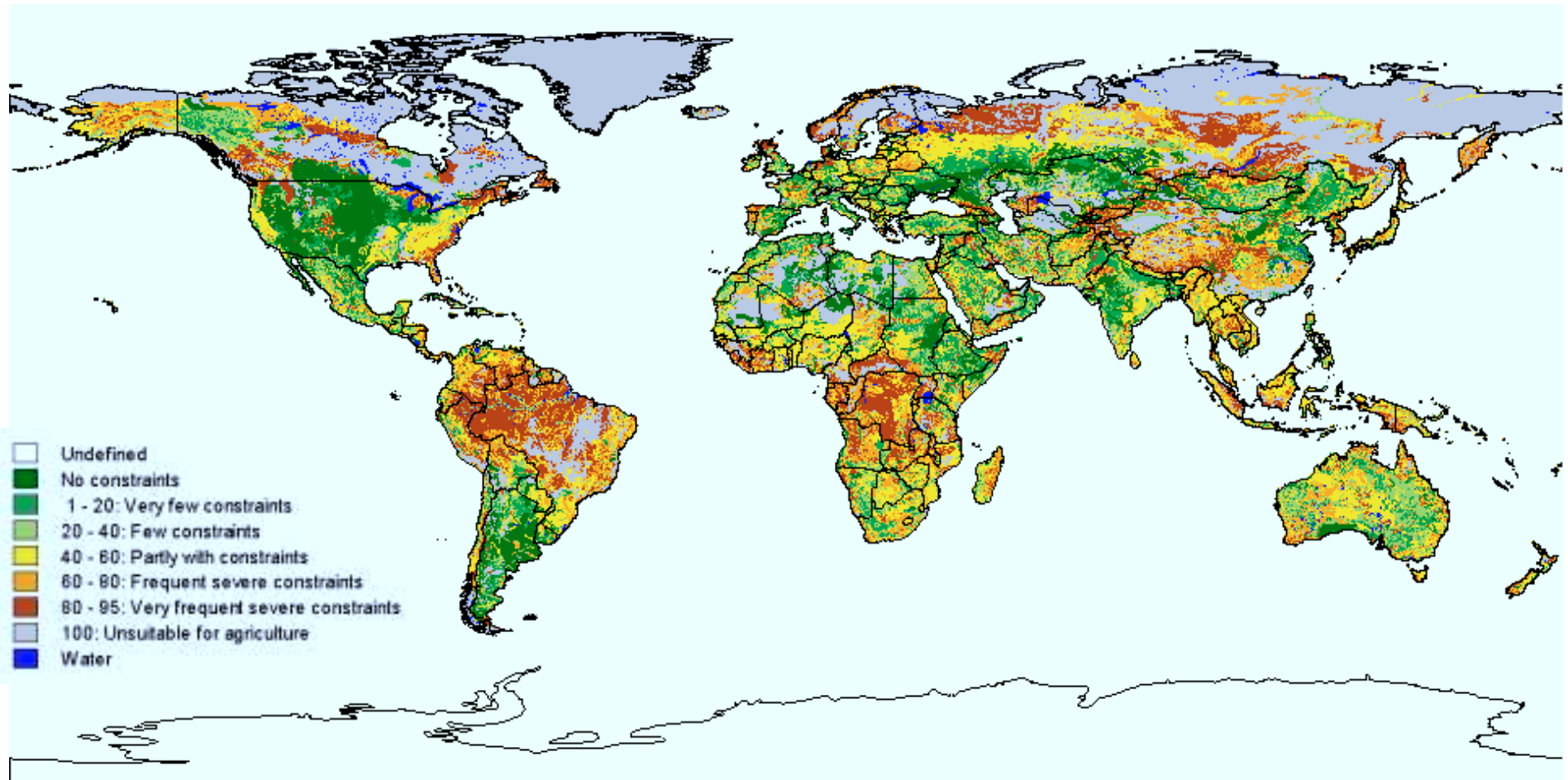


Plate 23. Soil drainage constraints

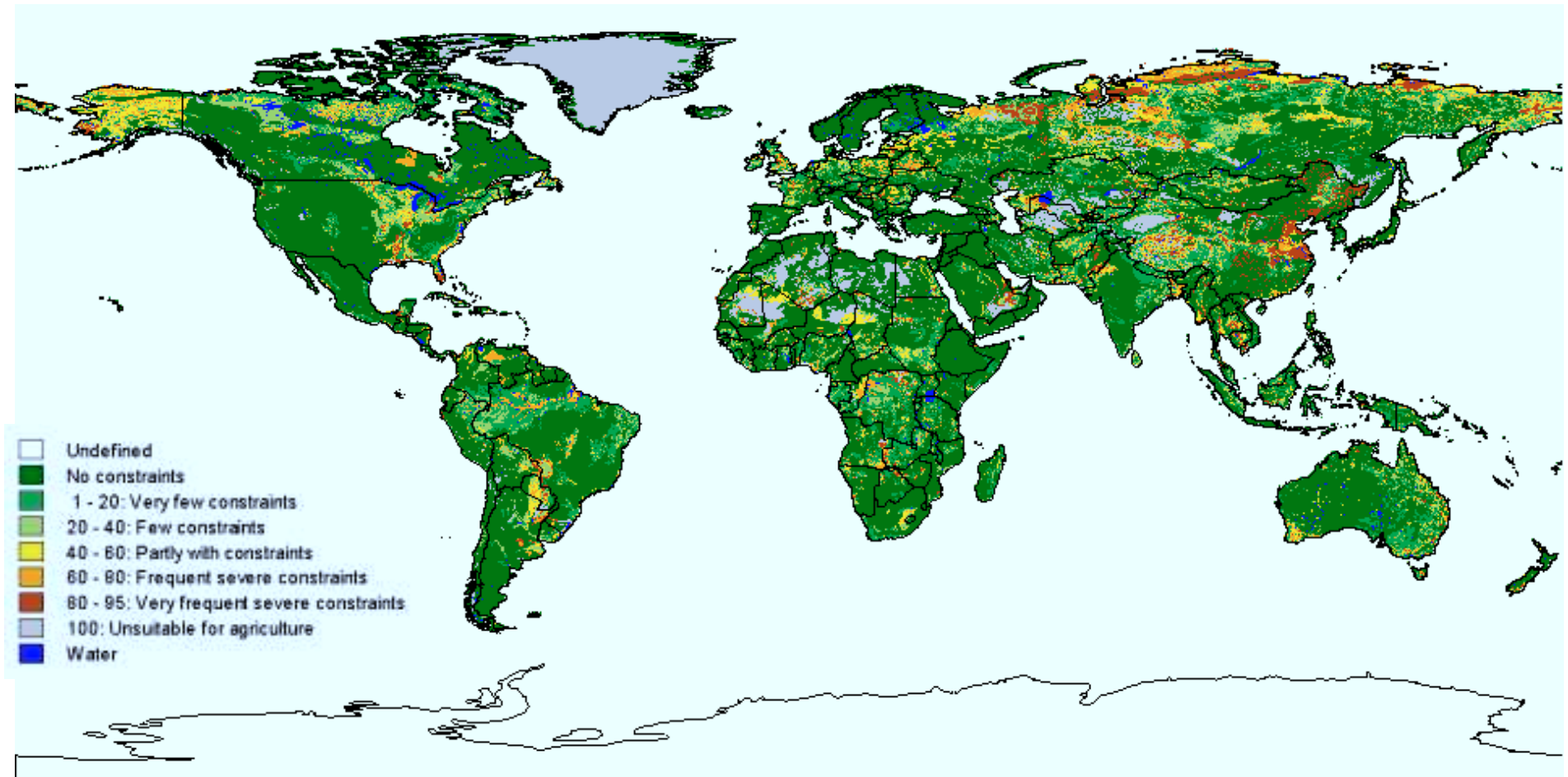


Plate 24. Soil texture constraints

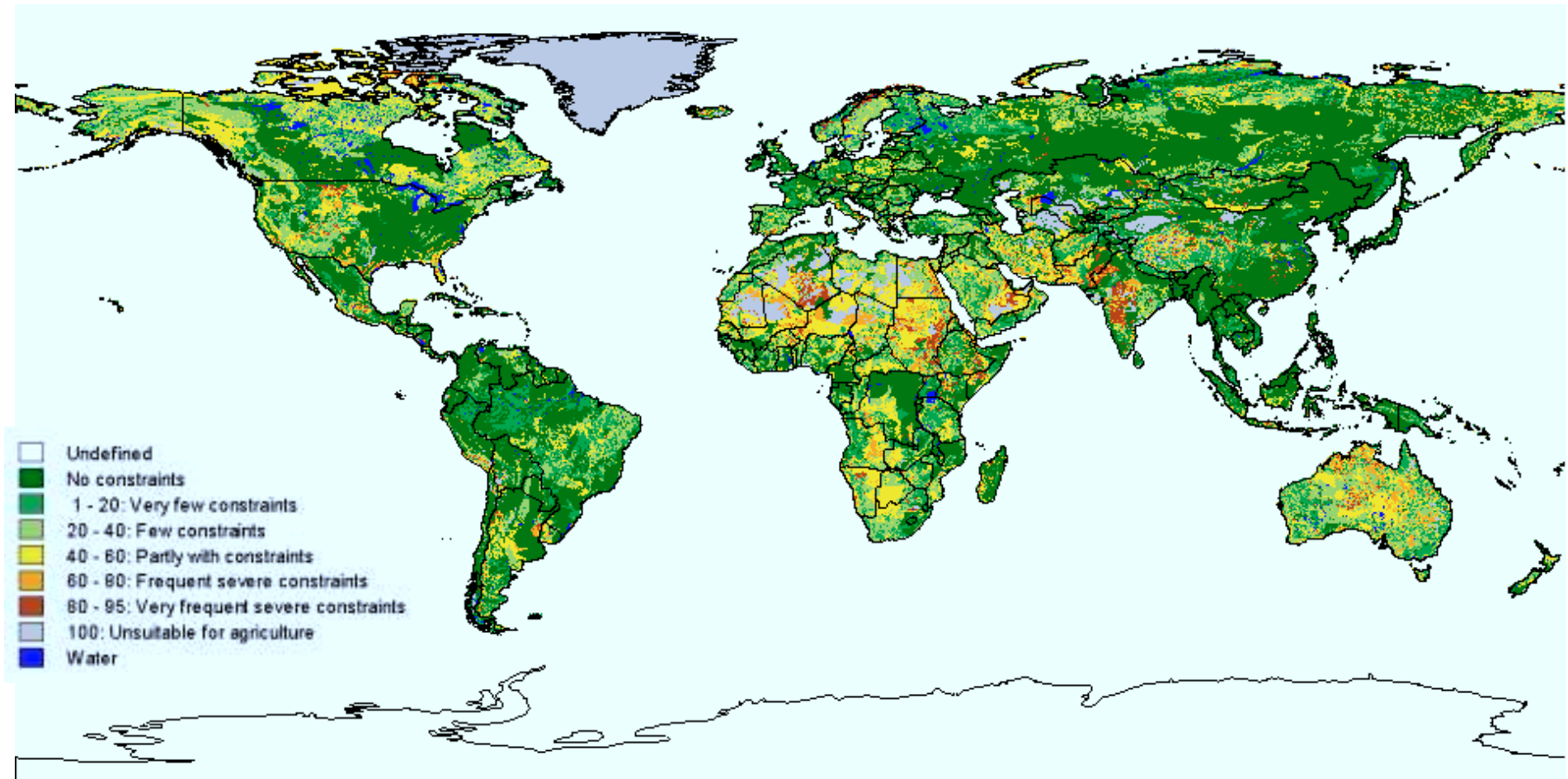


Plate 25. Soil chemical constraints

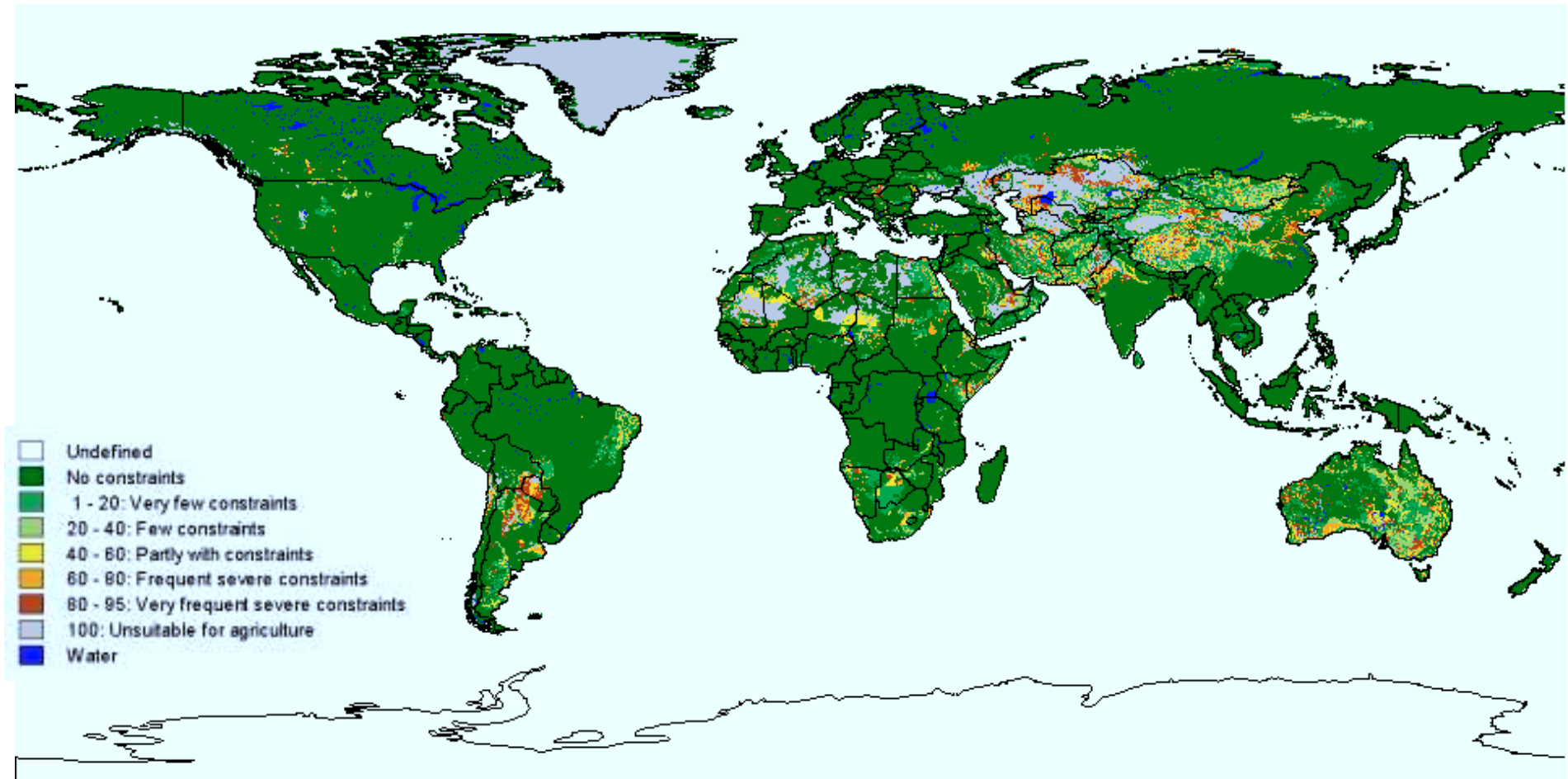


Plate 26. Terrain slope constraints

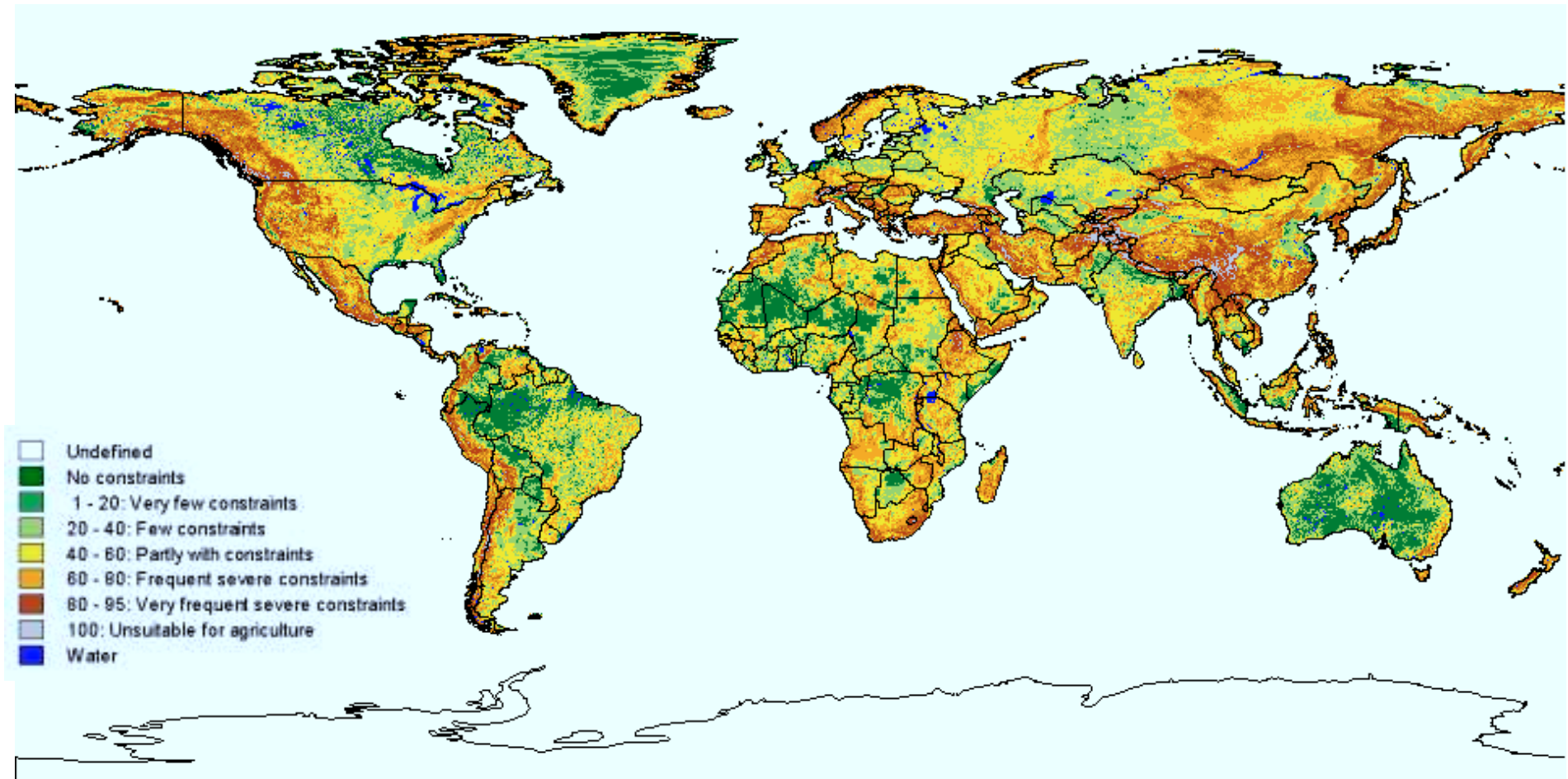


Plate 27. Soil constraints combined

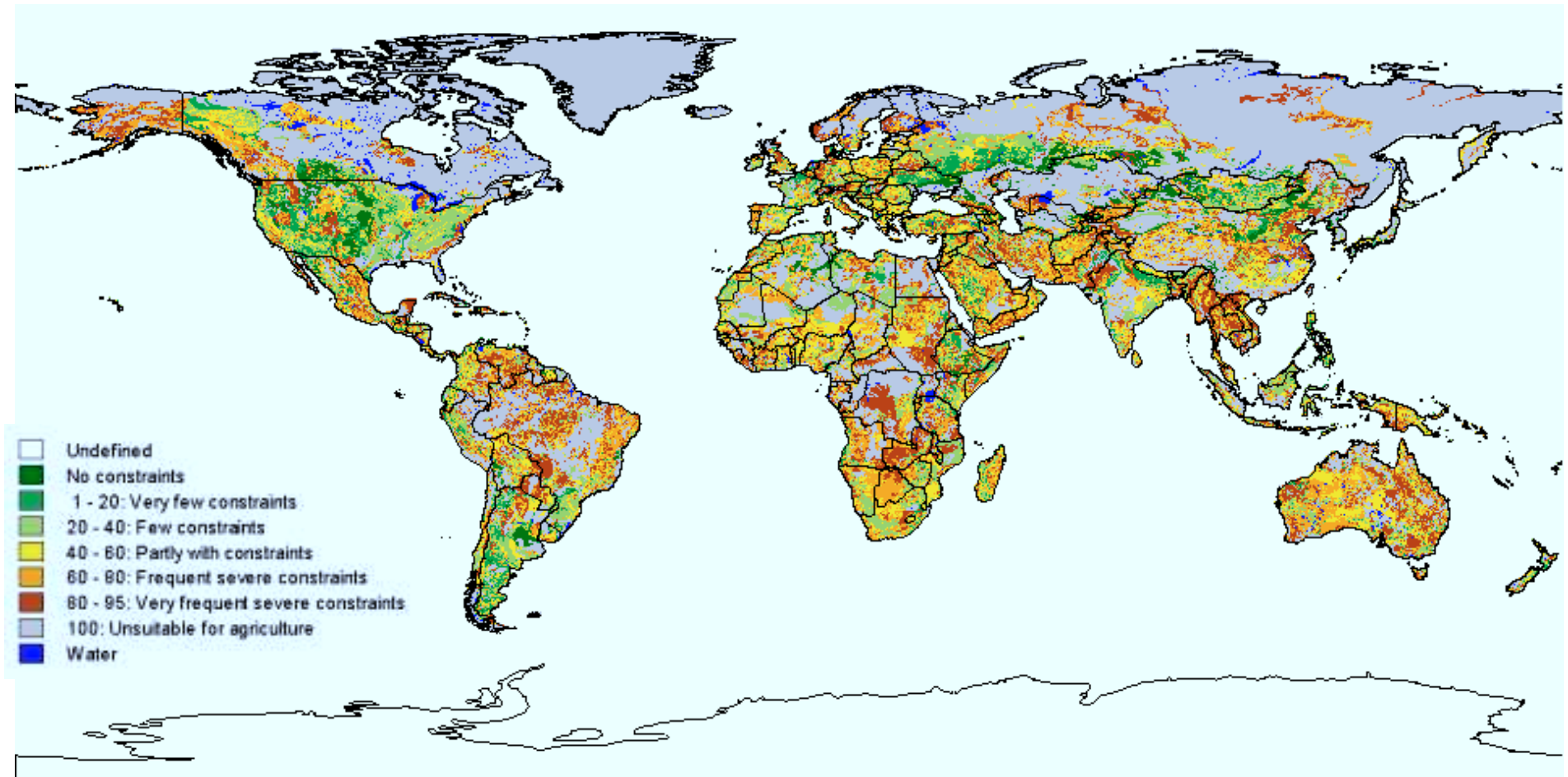


Plate 28. Climate, soil and terrain slope constraints combined

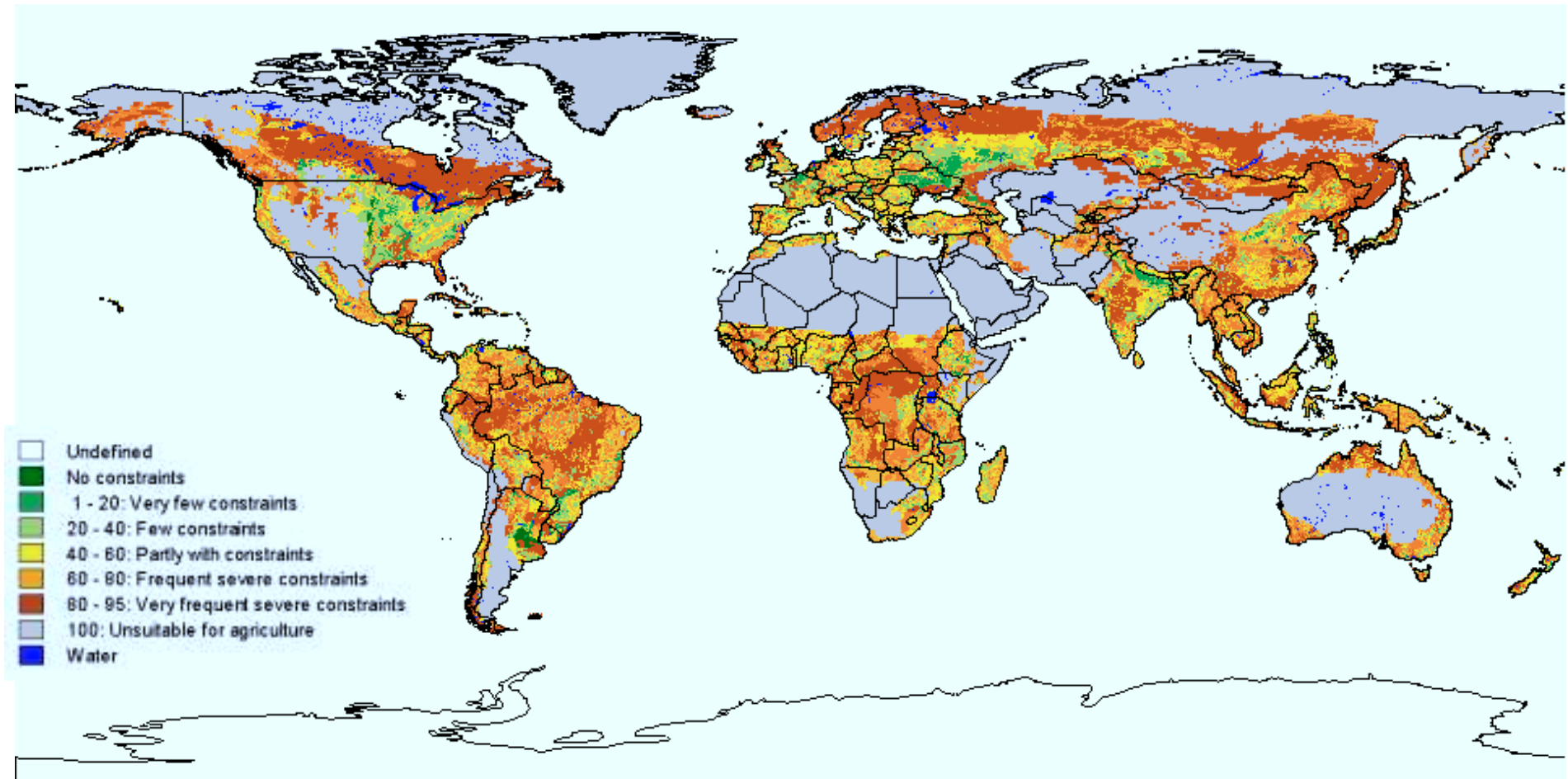


Plate 29. Suitability for rain-fed wheat (intermediate inputs)

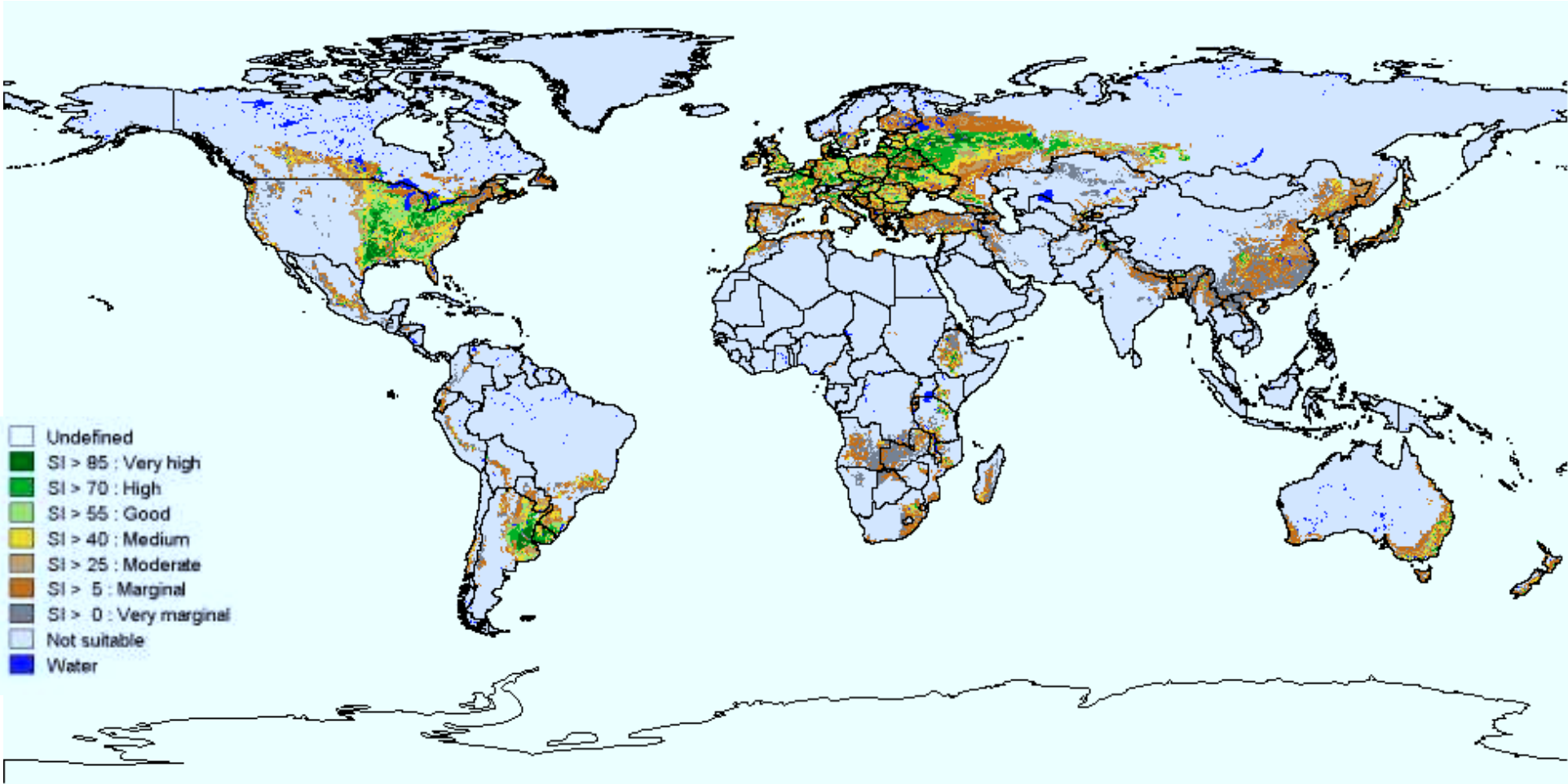


Plate 30. Suitability for rain-fed grain maize (intermediate inputs)

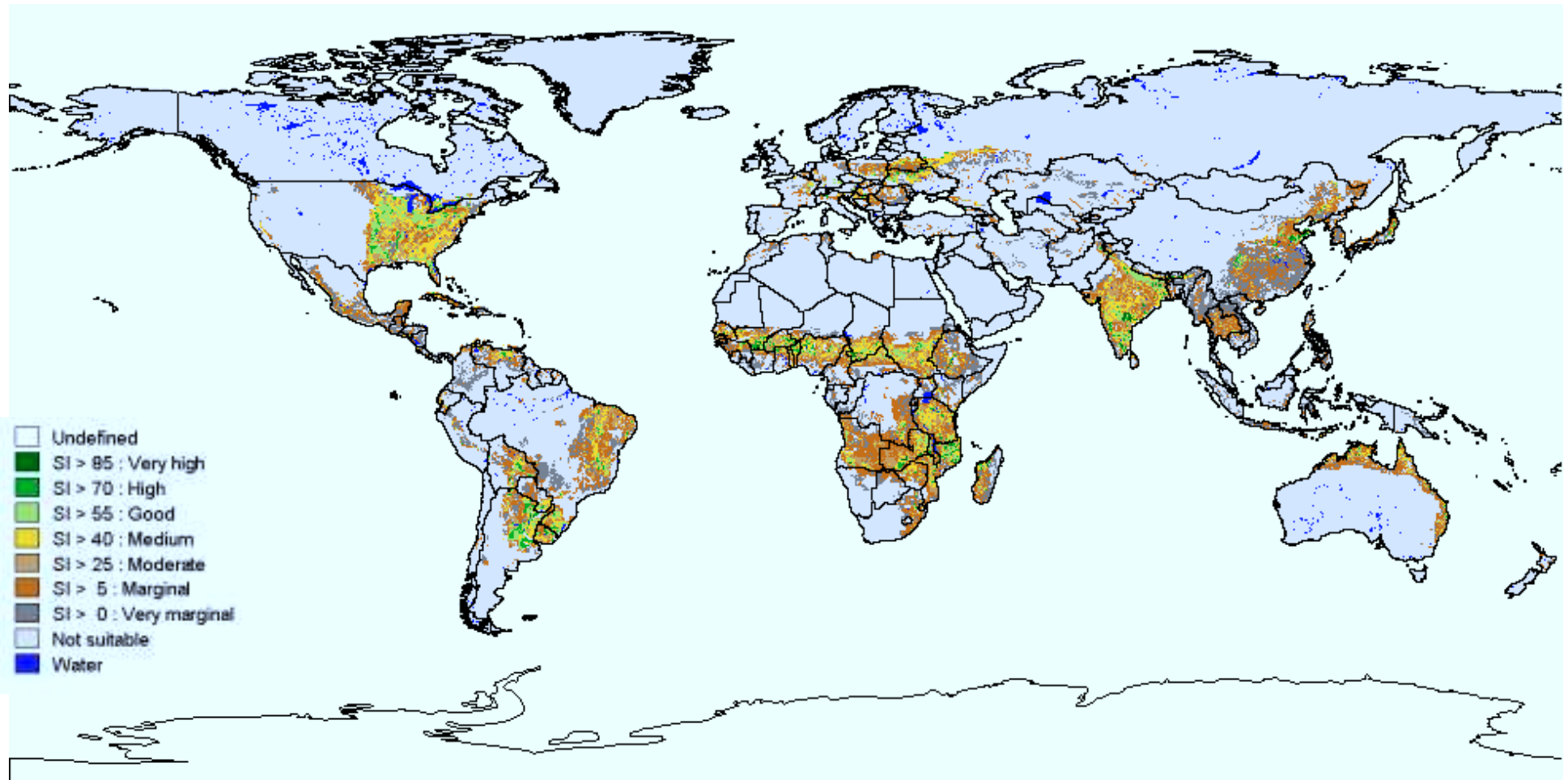


Plate 31. Suitability for rain-fed cereals (intermediate inputs)

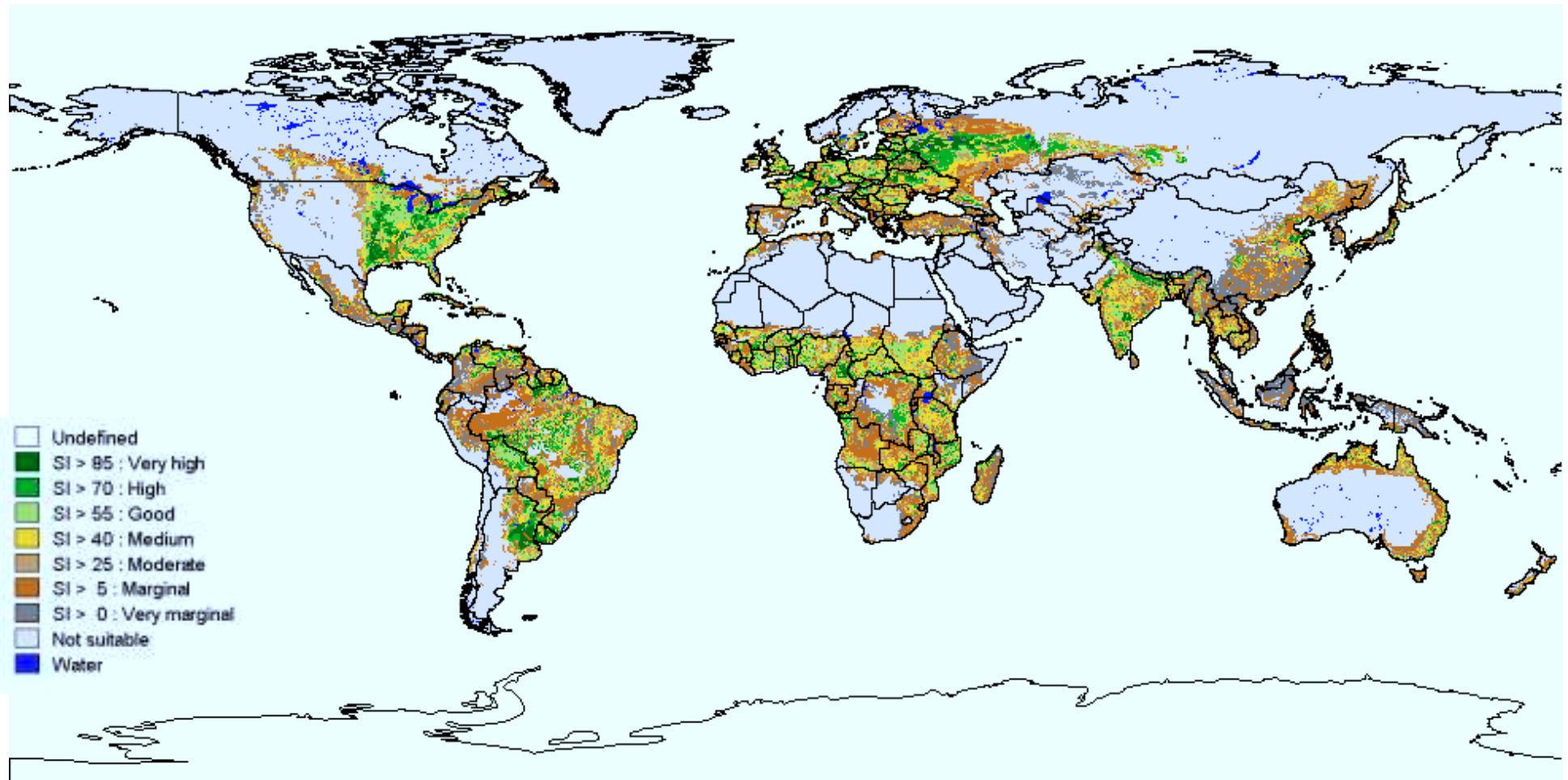


Plate 32. Suitability for rain-fed roots and tubers (intermediate inputs)

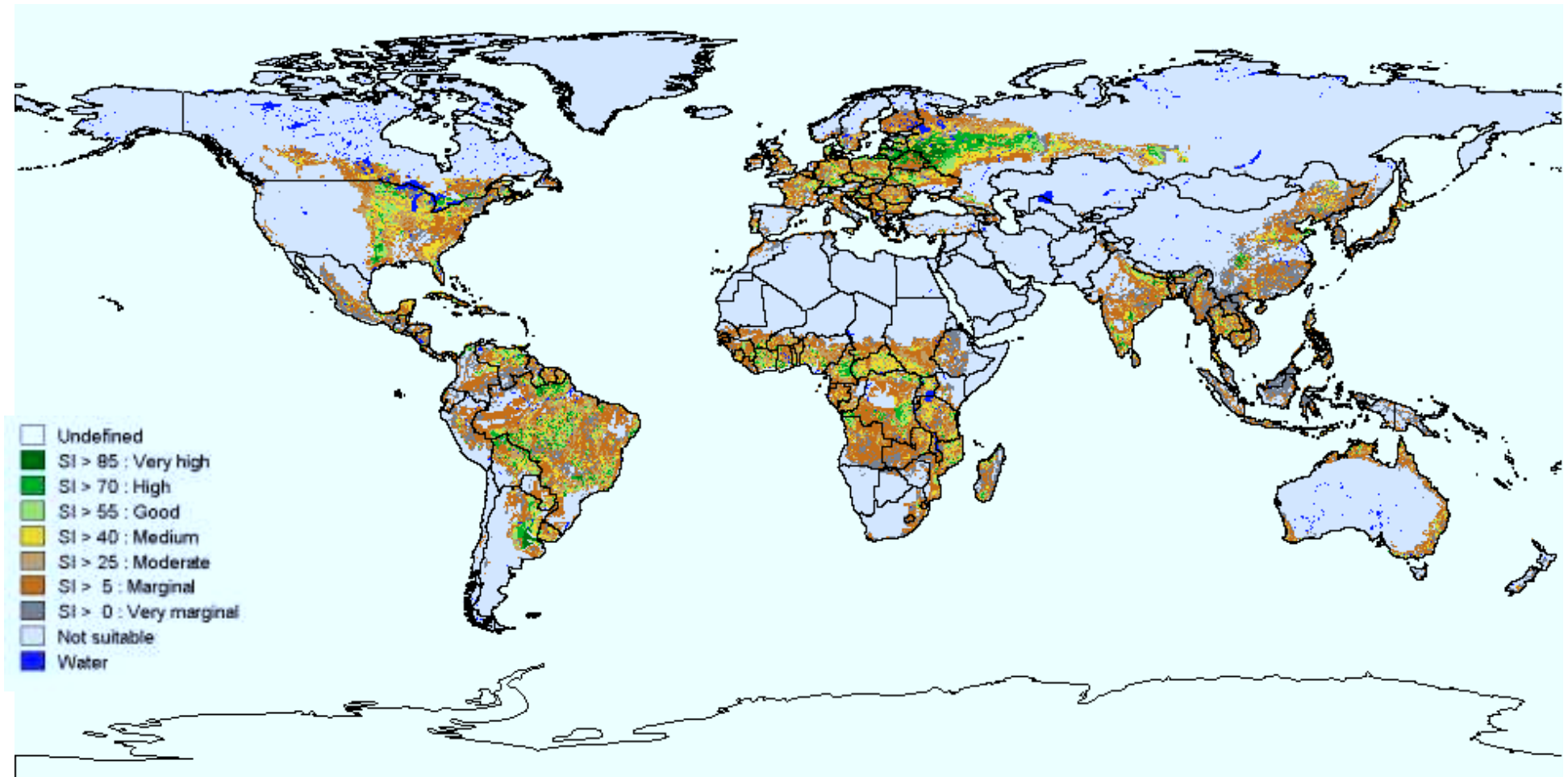


Plate 33. Suitability for rain-fed pulses (intermediate inputs)

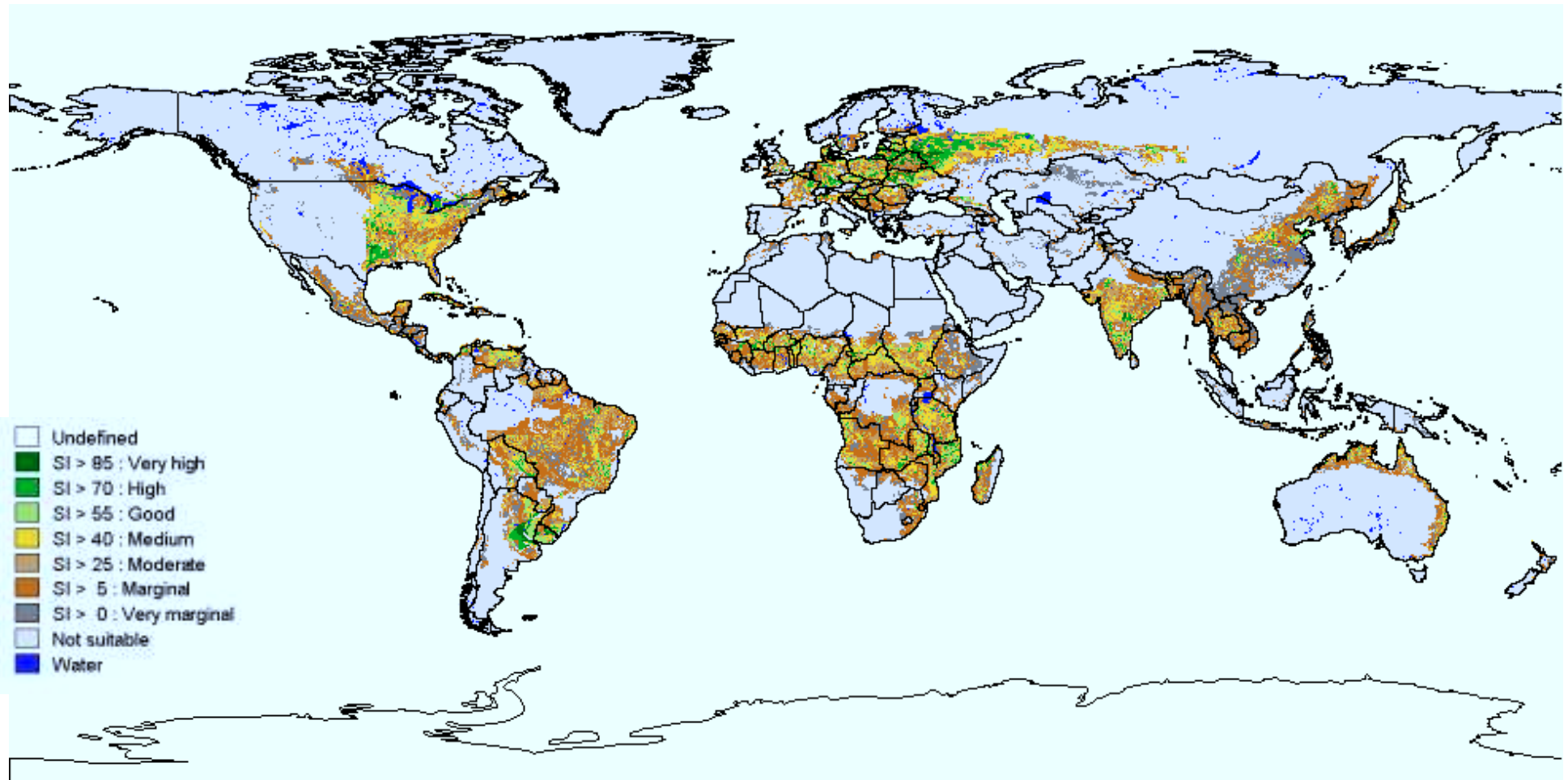


Plate 34. Suitability for rain-fed oil crops (intermediate inputs)

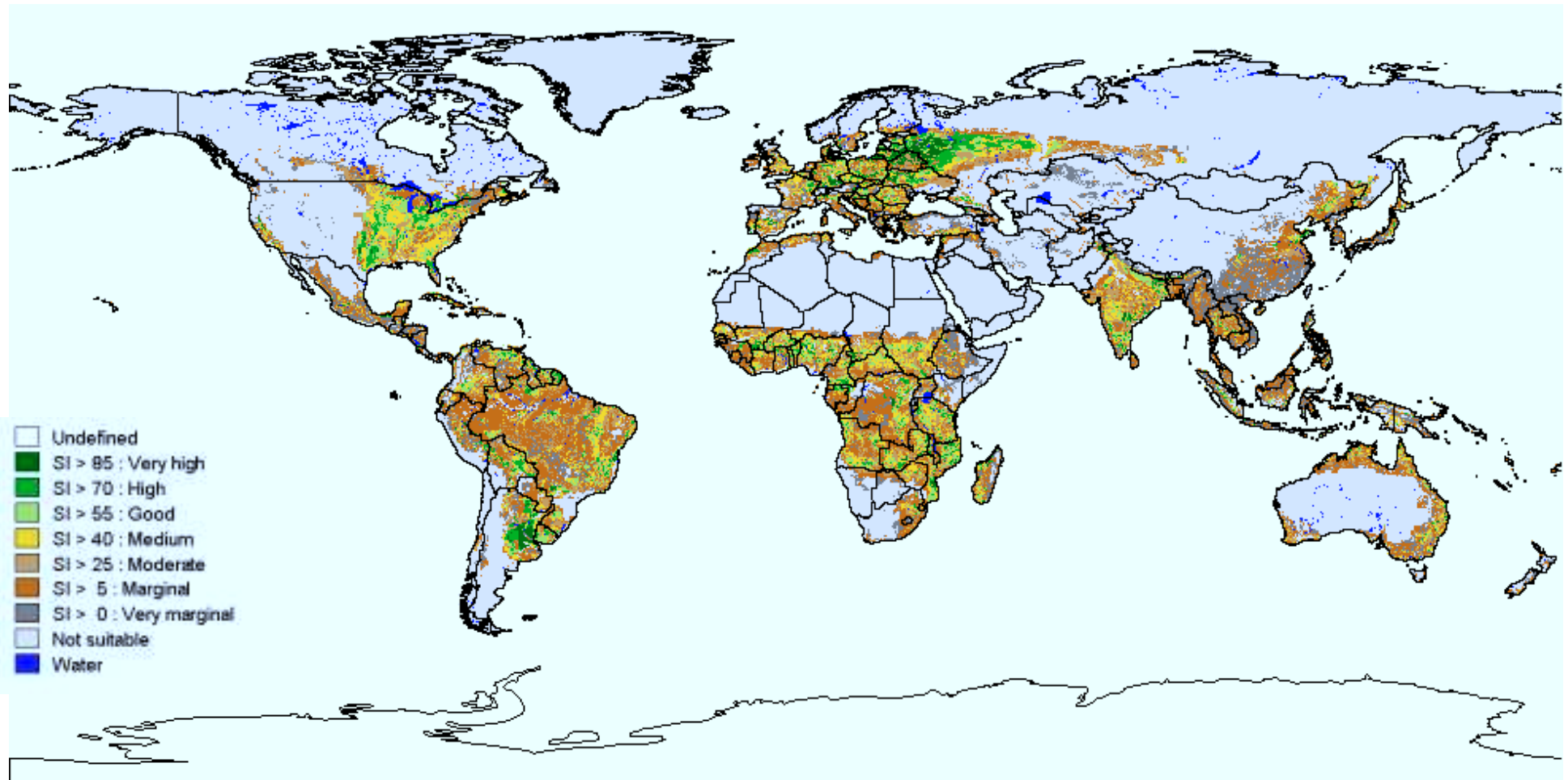


Plate 35. Suitability for rain-fed sugar crops (intermediate inputs)

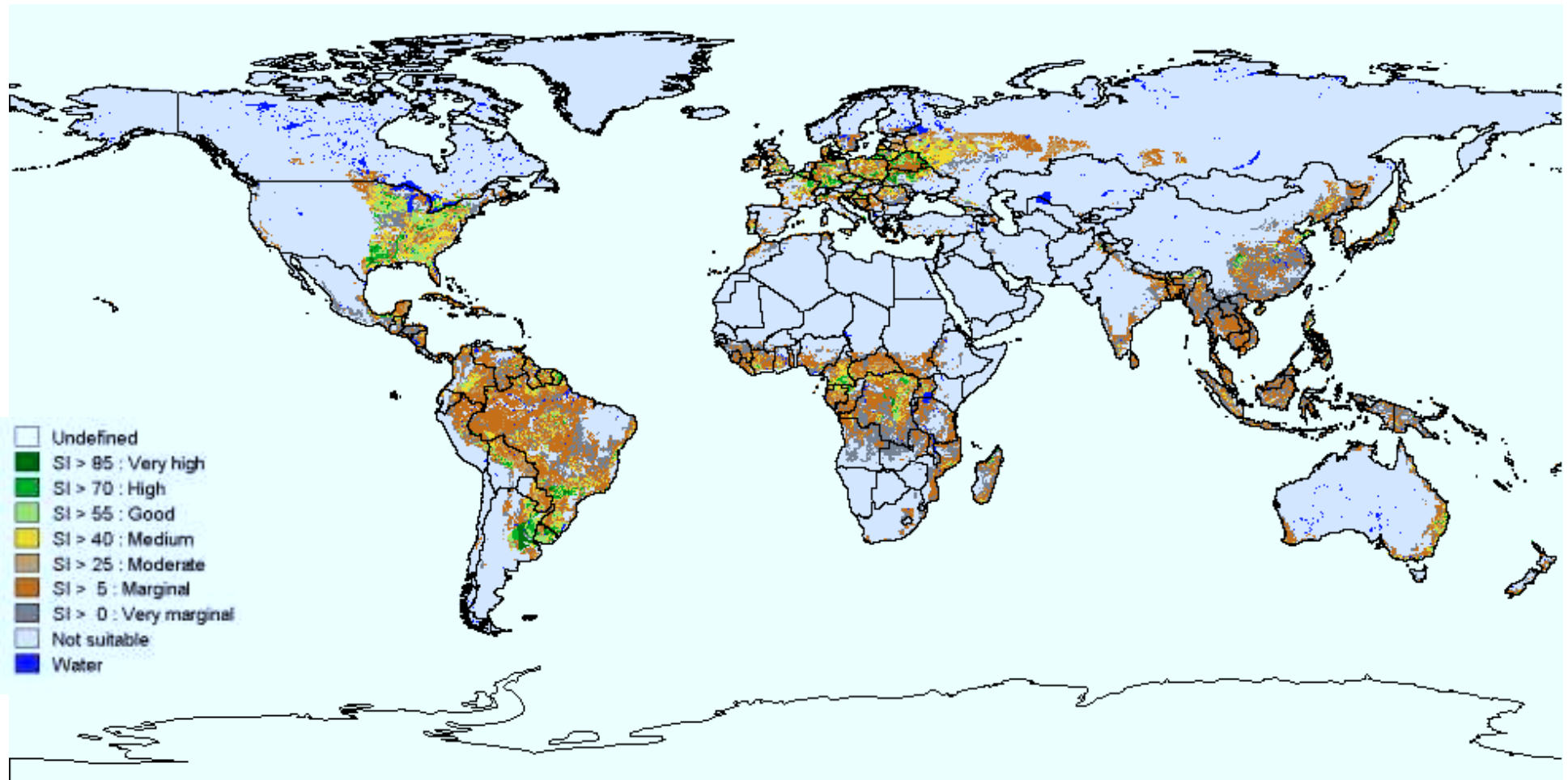


Plate 36. Suitability for rain-fed cotton (intermediate inputs)

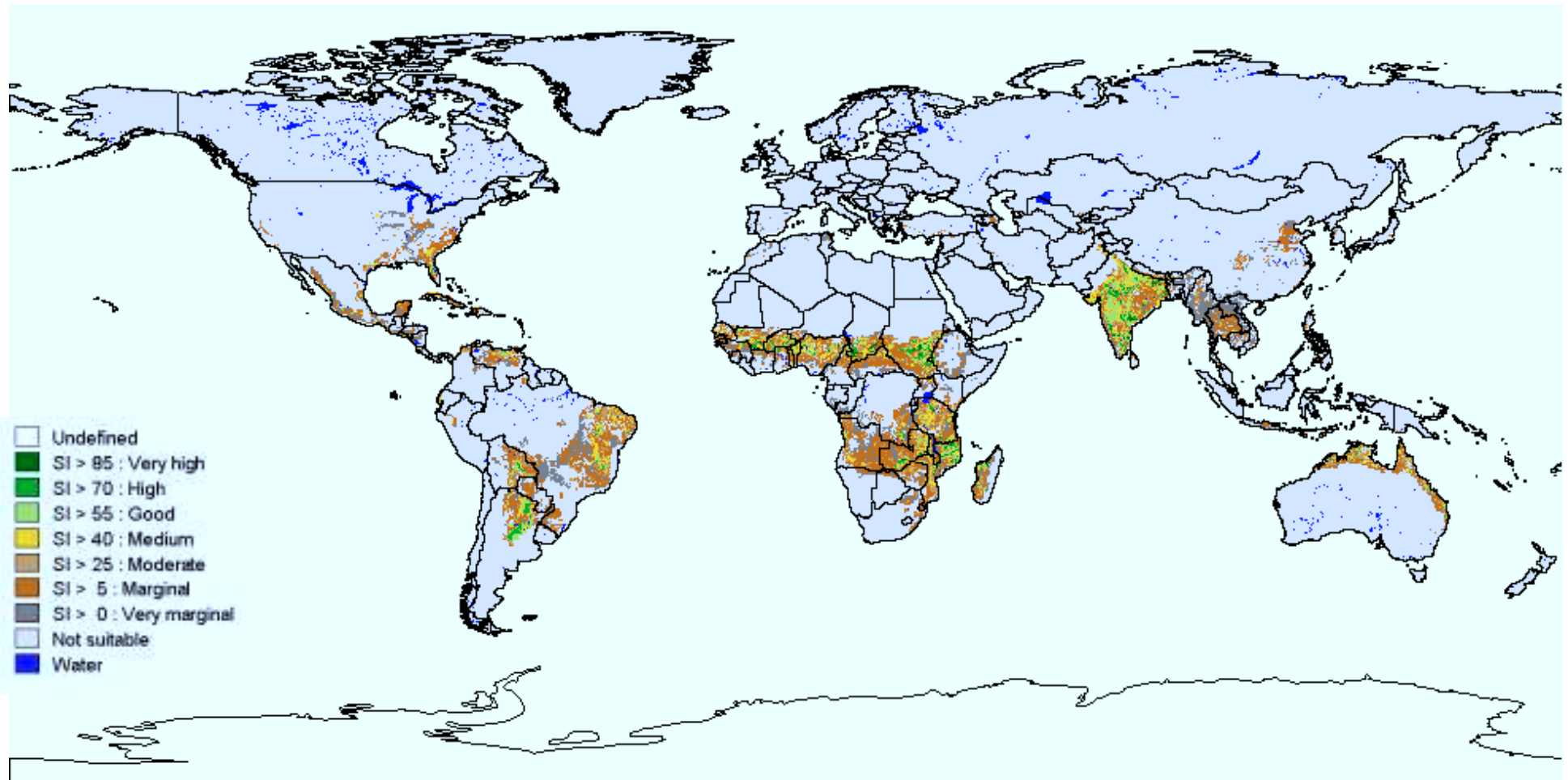


Plate 37. Suitability for rain-fed and irrigated wheat (high inputs)

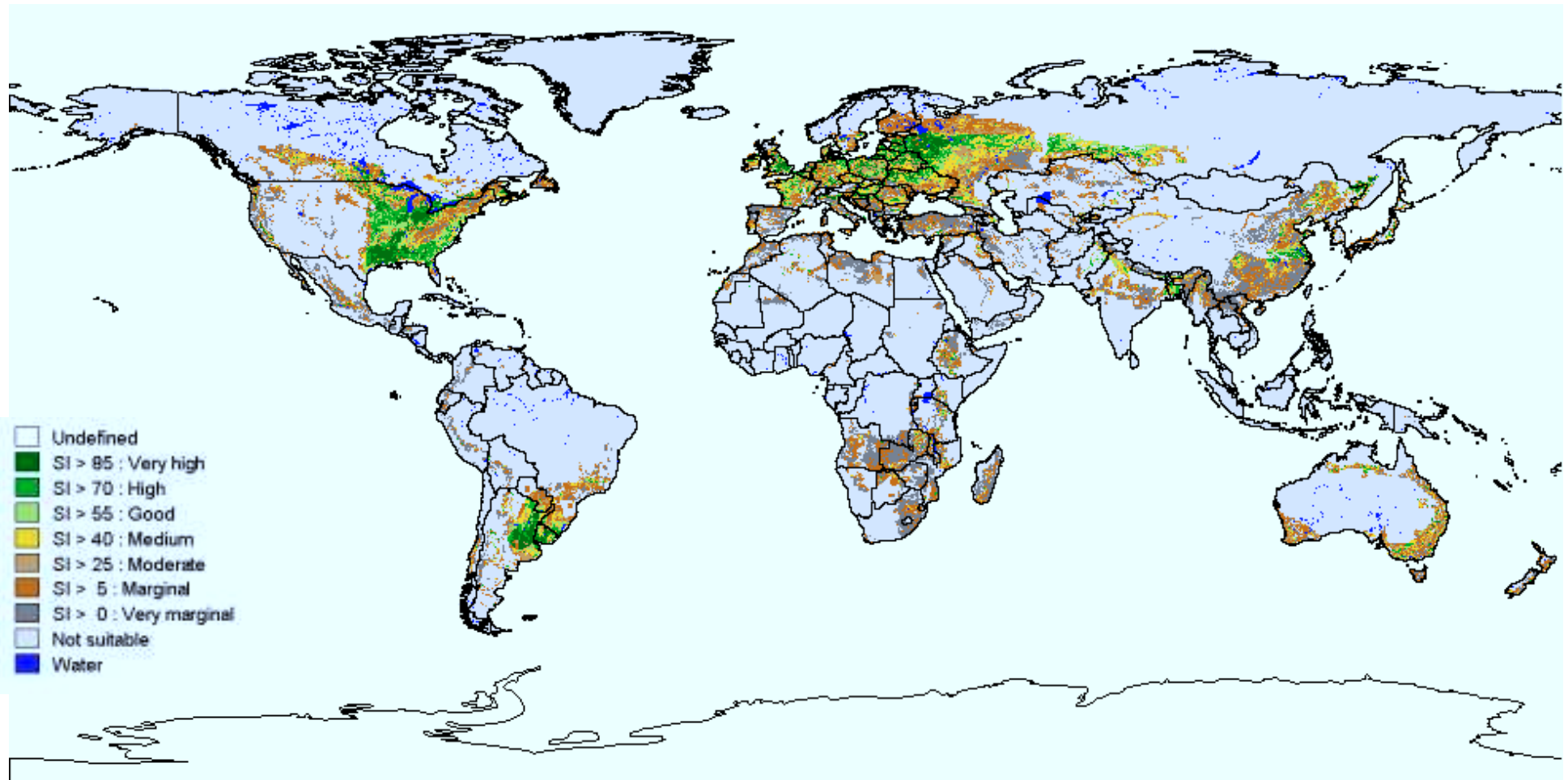


Plate 38. Suitability for rain-fed and irrigated rice (high inputs)

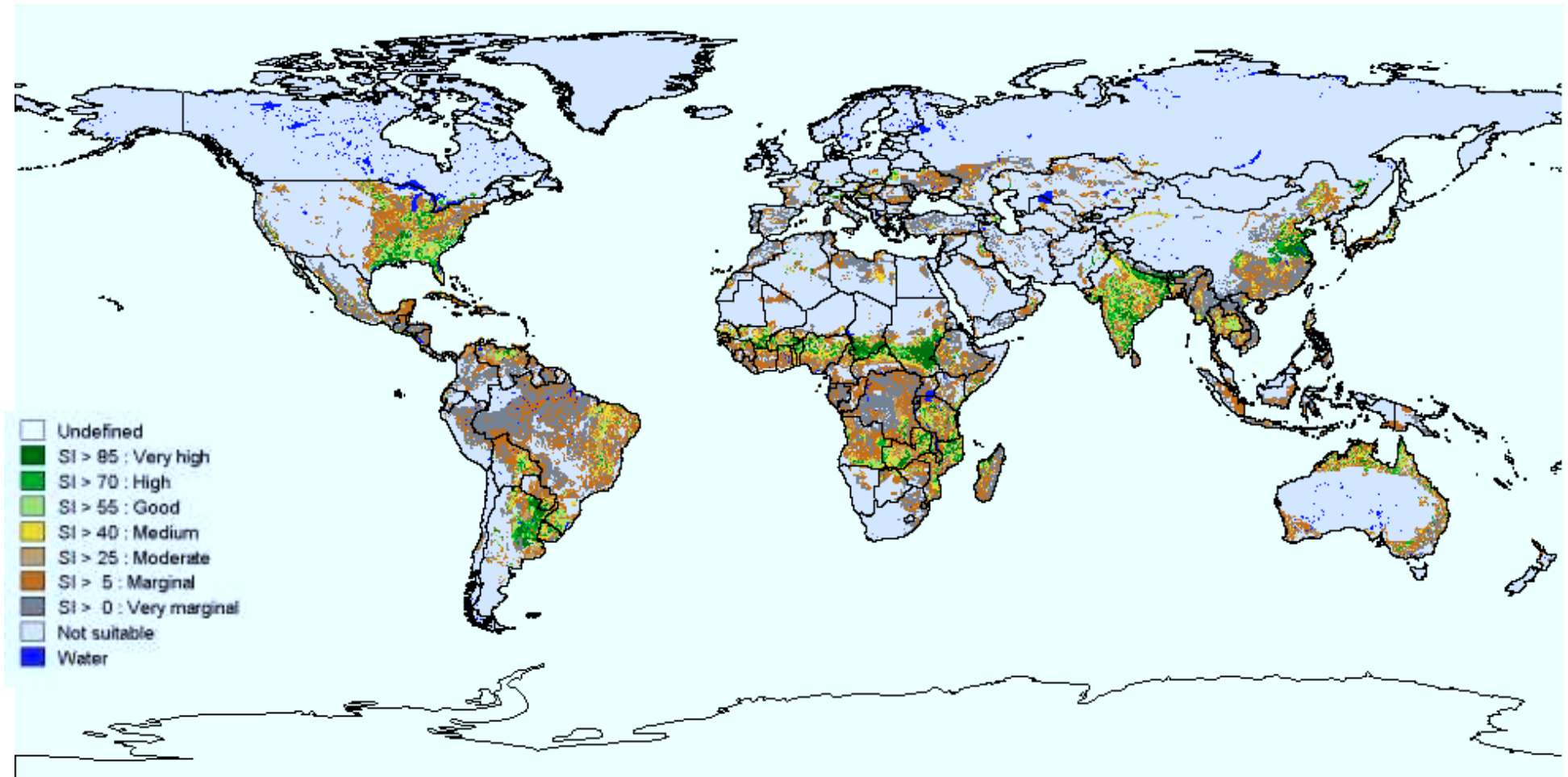


Plate 39. Suitability for rain-fed and irrigated grain maize (high inputs)

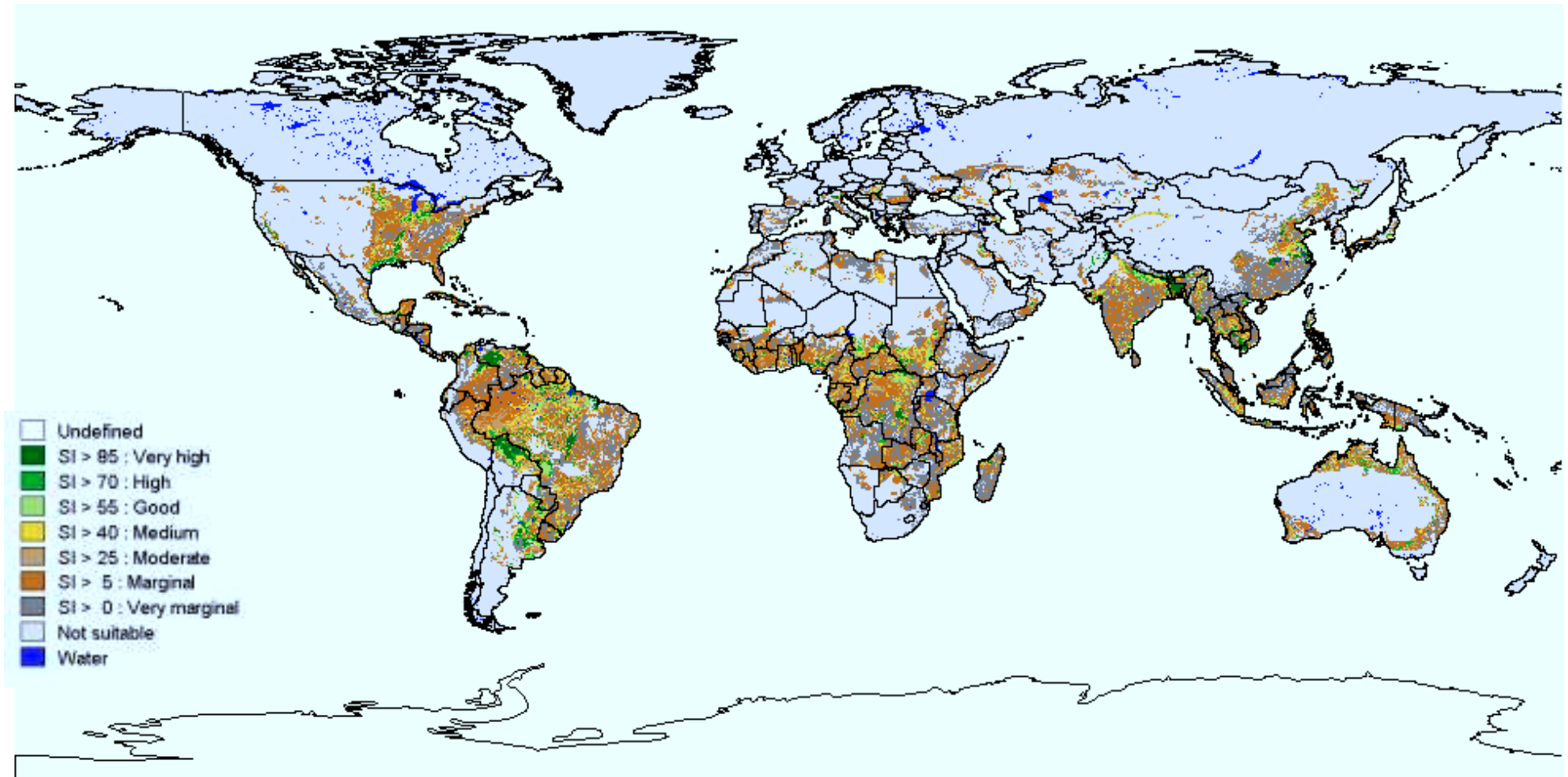


Plate 40. Suitability for rain-fed and irrigated cereals (high inputs)

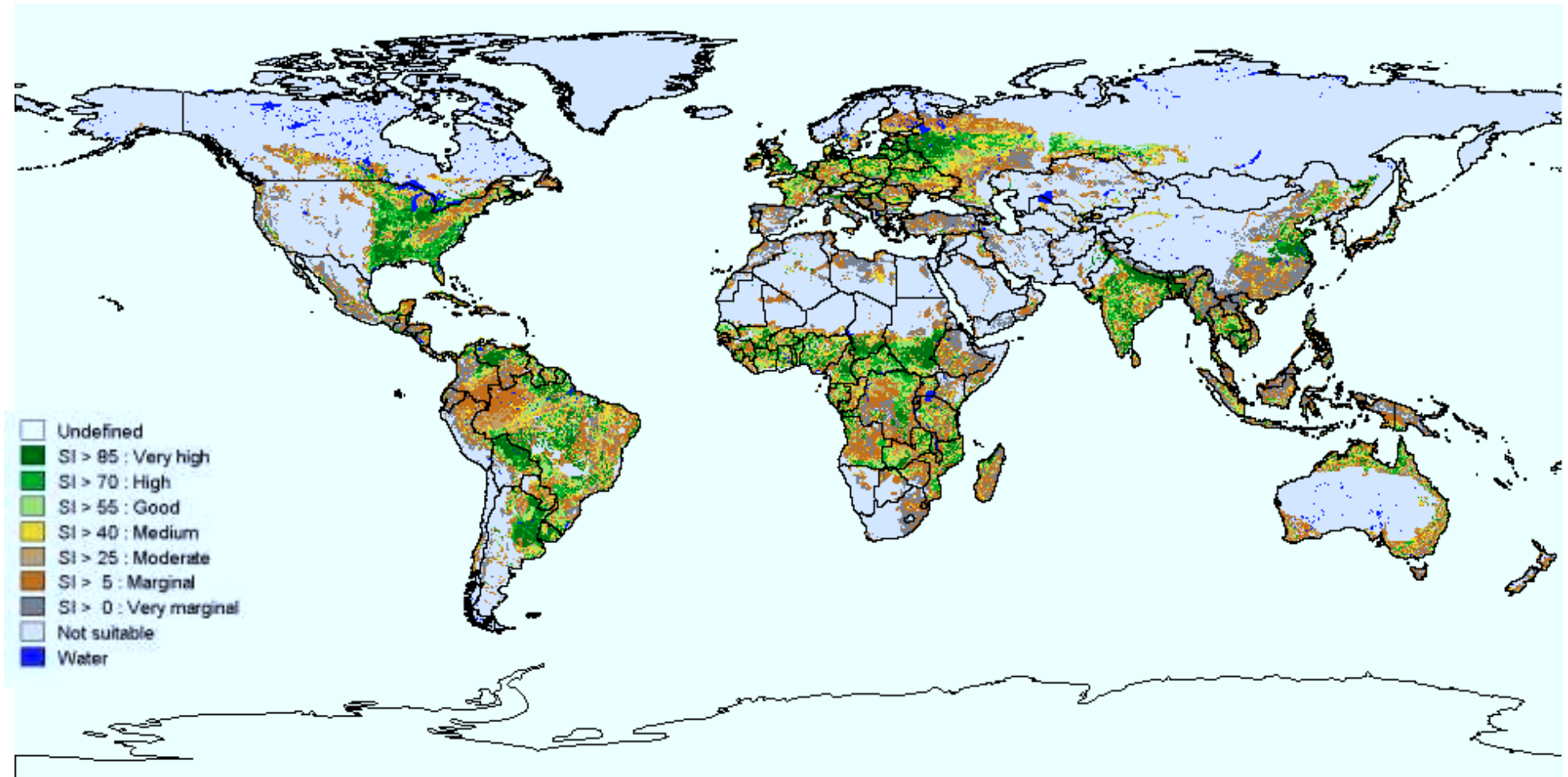


Plate 41. Suitability for rain-fed and irrigated roots and tubers (high inputs)

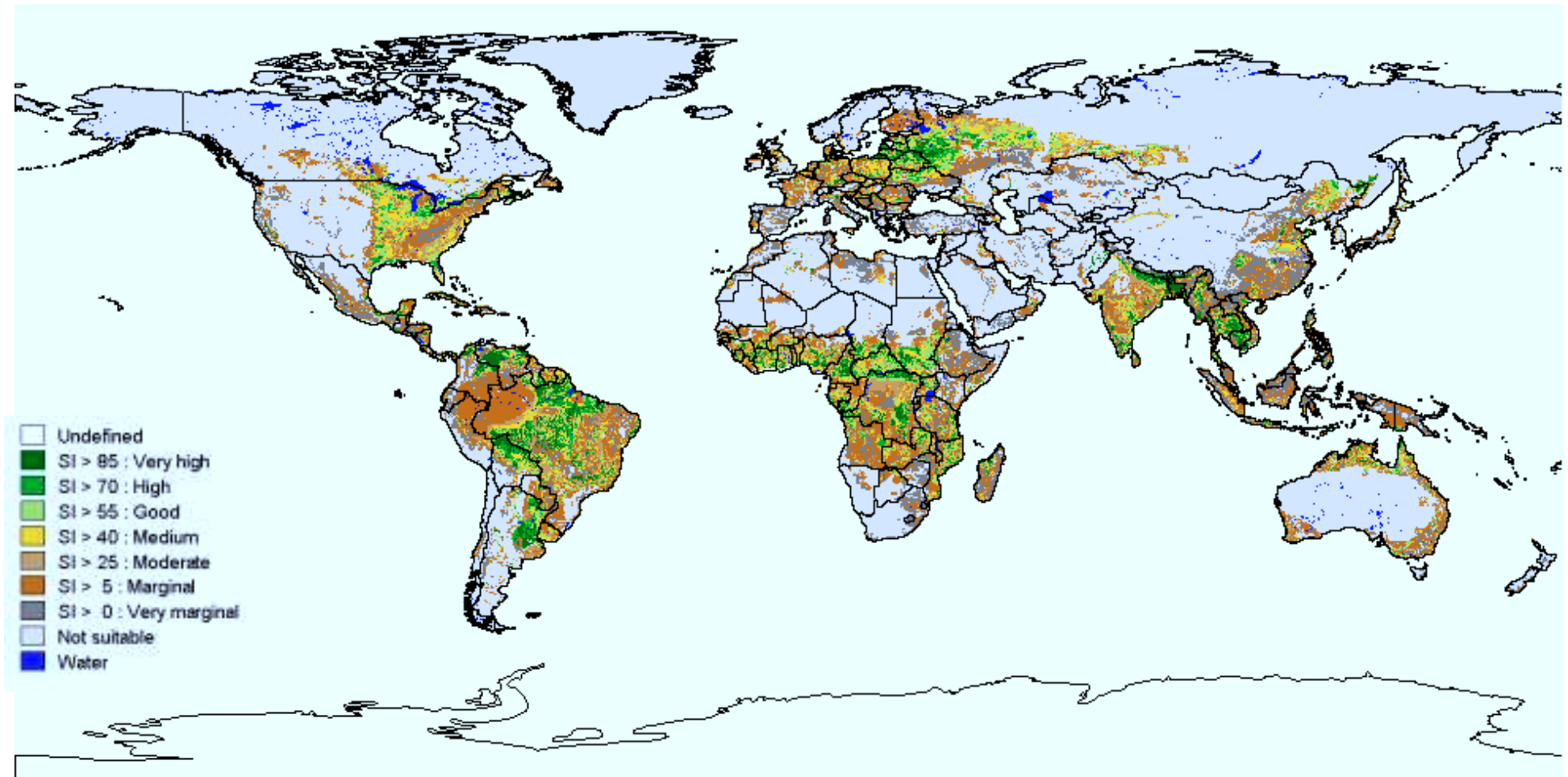


Plate 42. Suitability for rain-fed and irrigated pulses (high inputs)

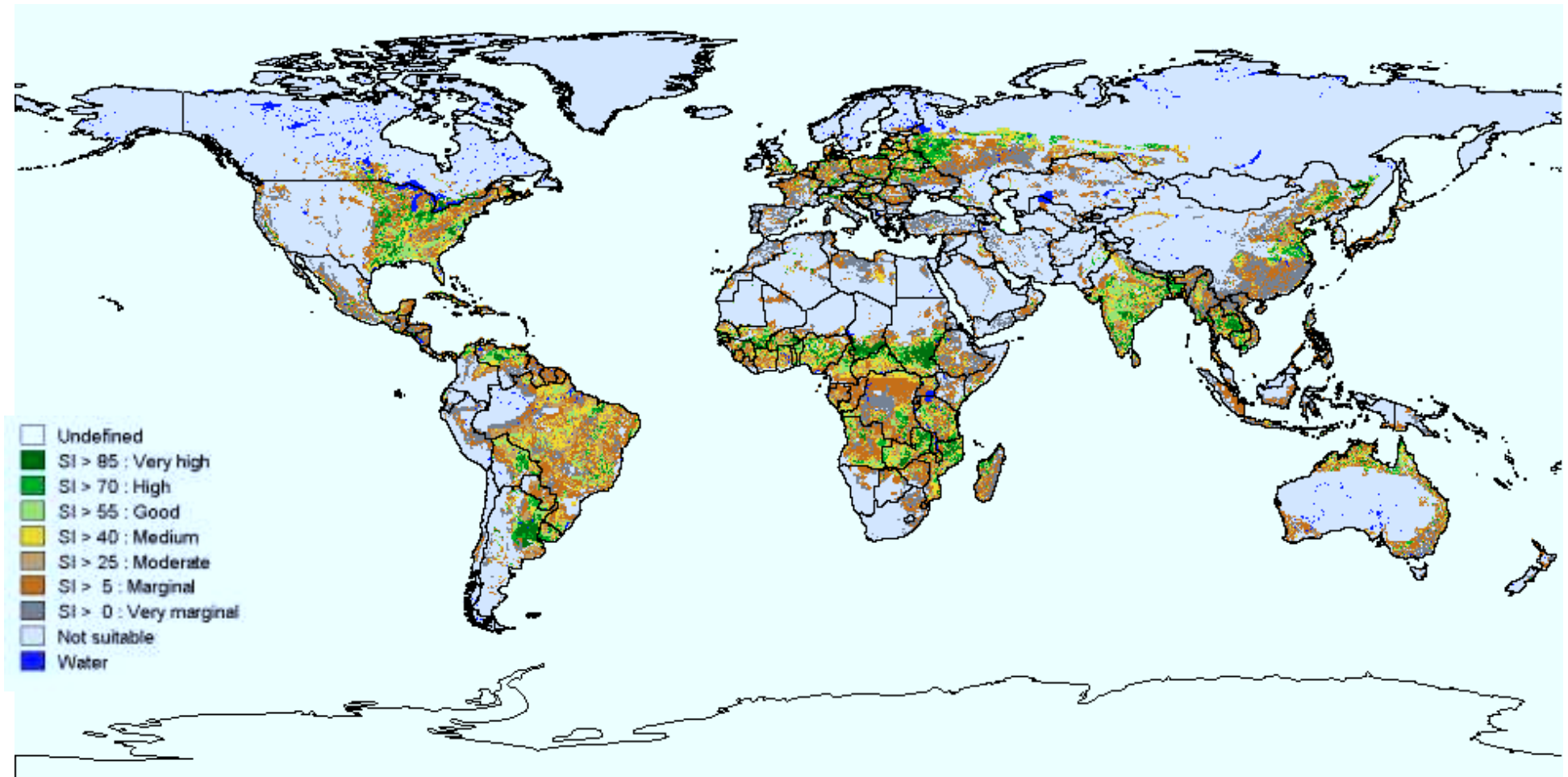


Plate 43. Suitability for rain-fed and irrigated oil crops (high inputs)

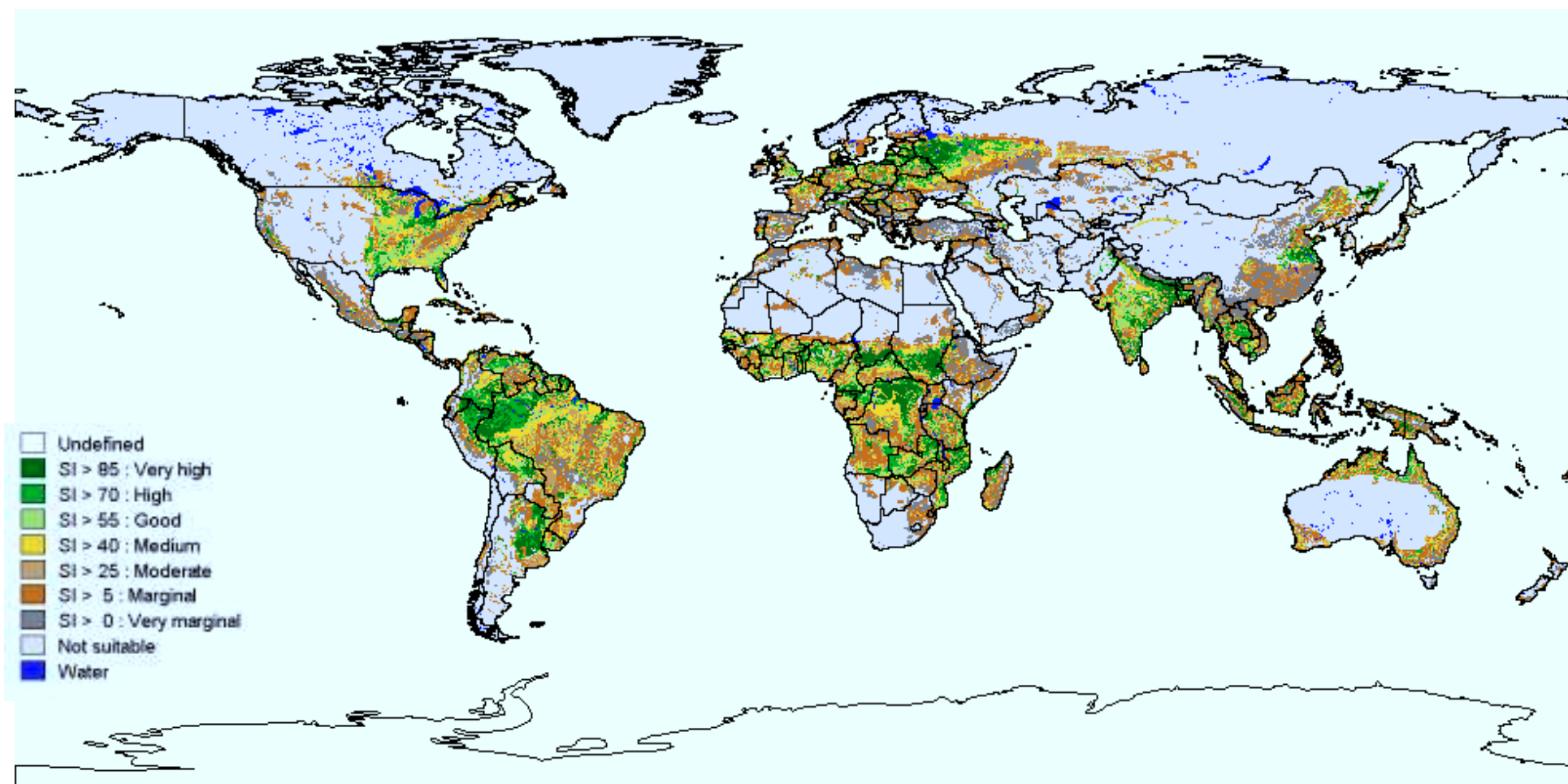


Plate 44. Suitability for rain-fed and irrigated sugar crops (high inputs)

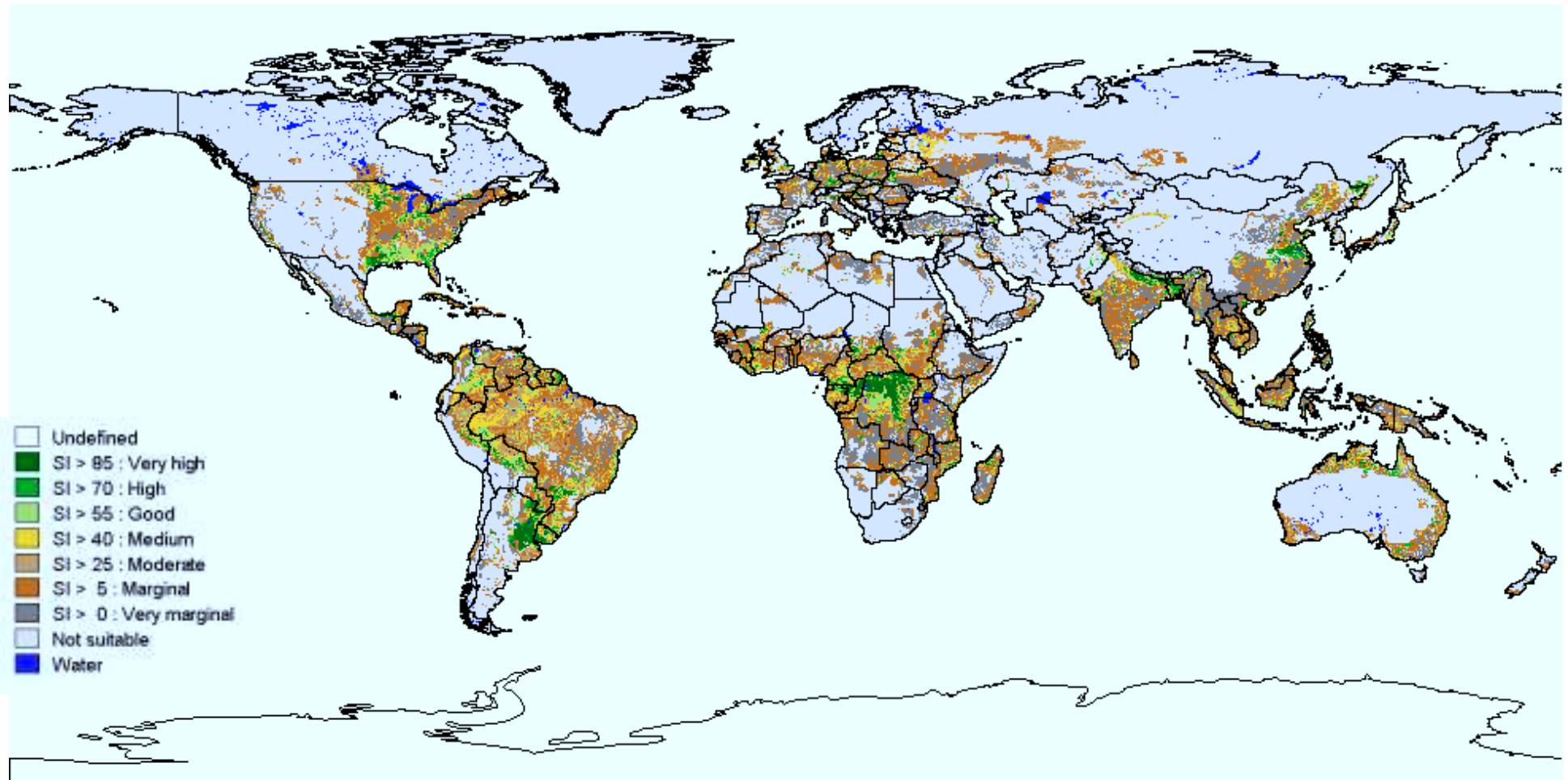


Plate 45. Suitability for rain-fed and irrigated cotton (high inputs)

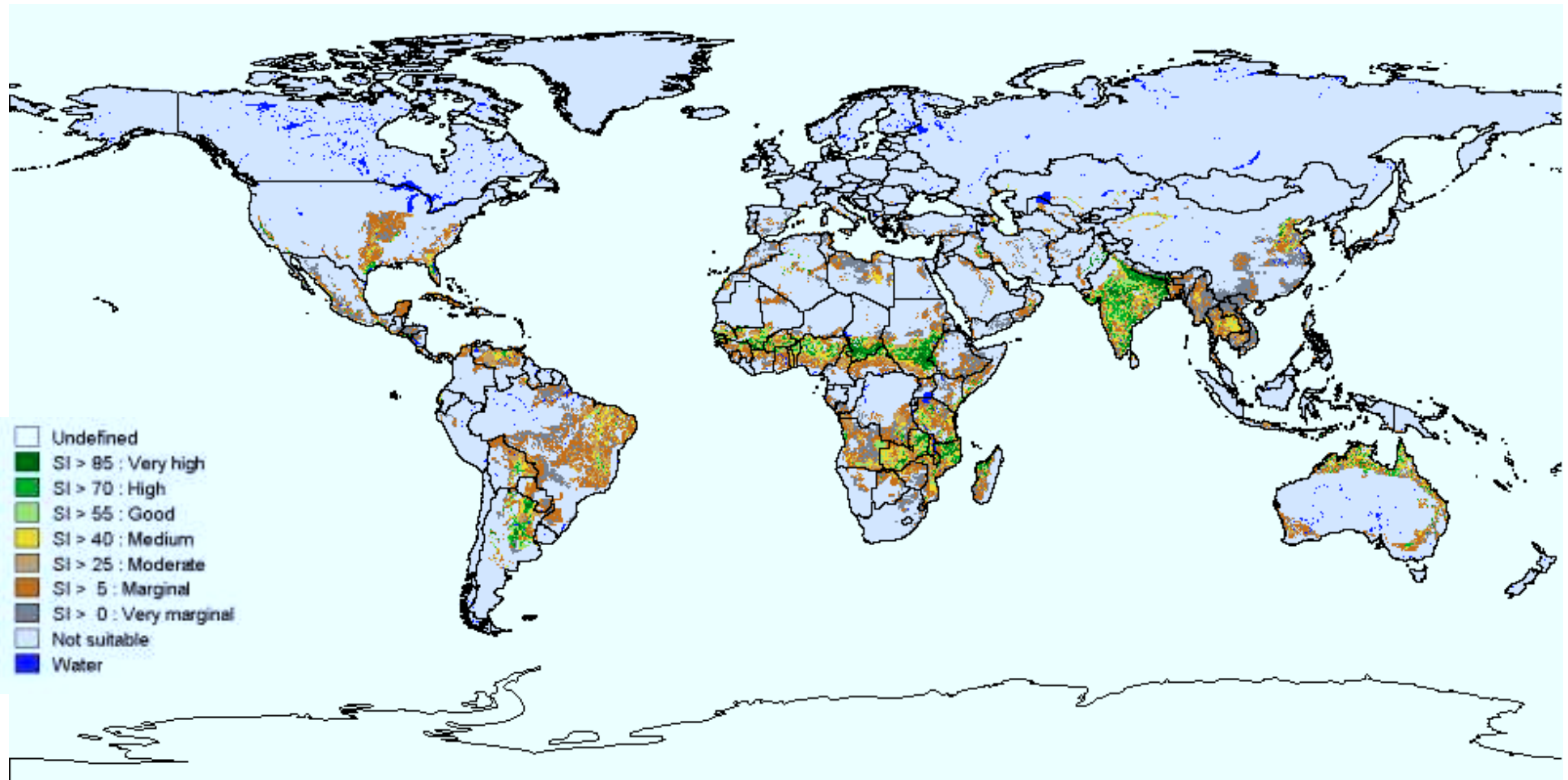


Plate 46. Suitability for rain-fed crops - maximizing technology mix

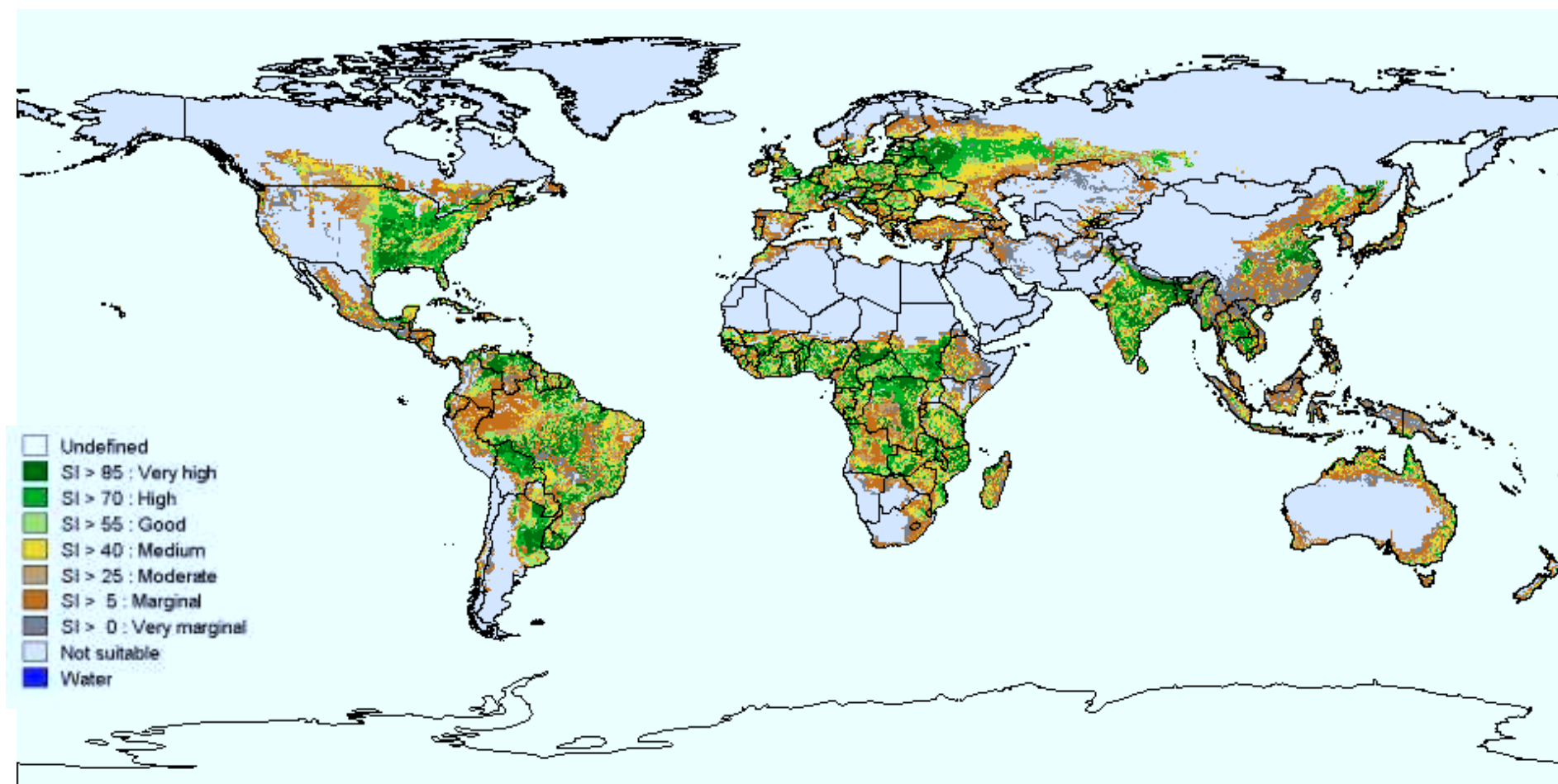


Plate 47. Irrigation impact classes

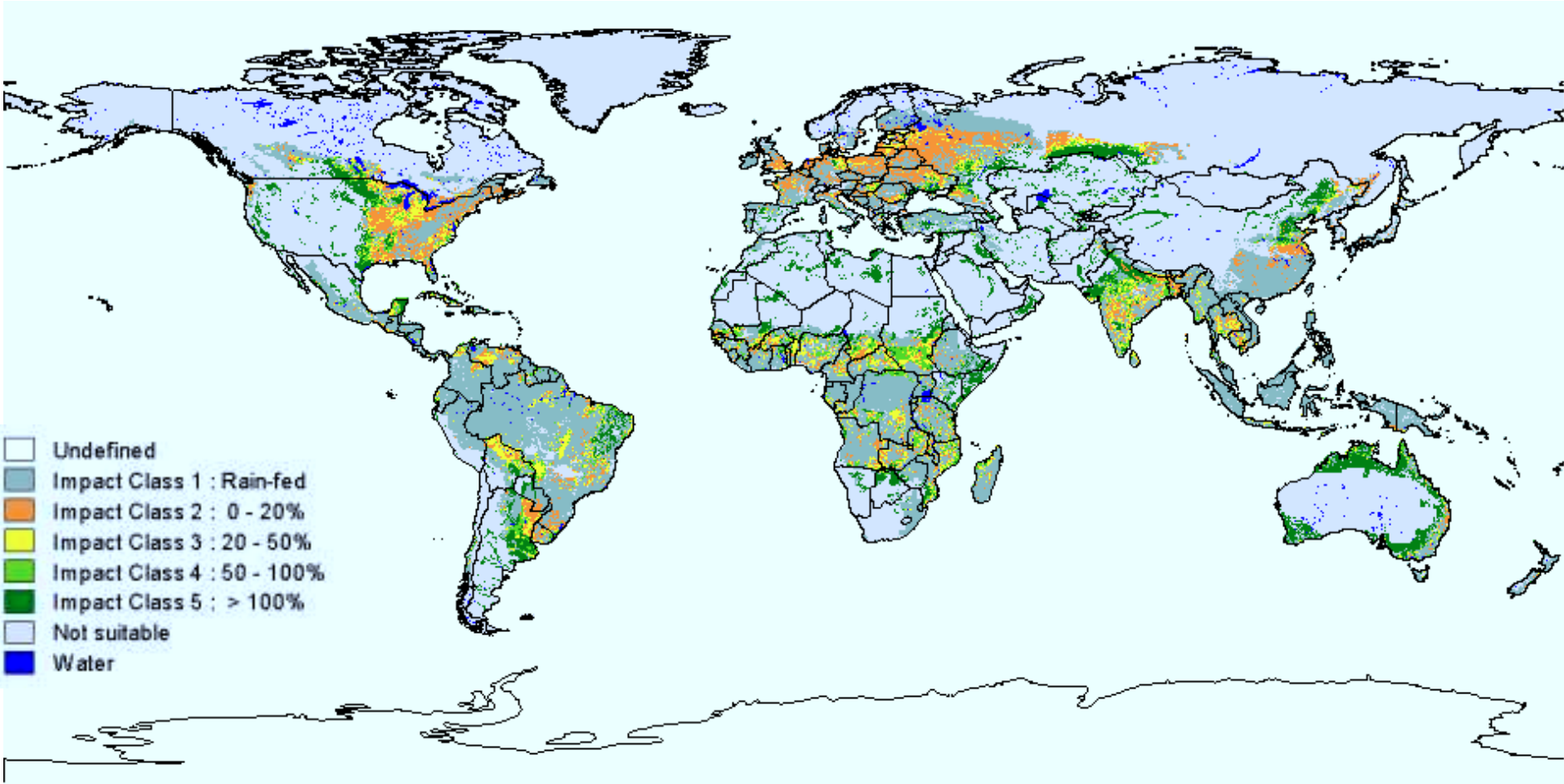


Plate 48. Most suitable cereal (agronomic suitability)

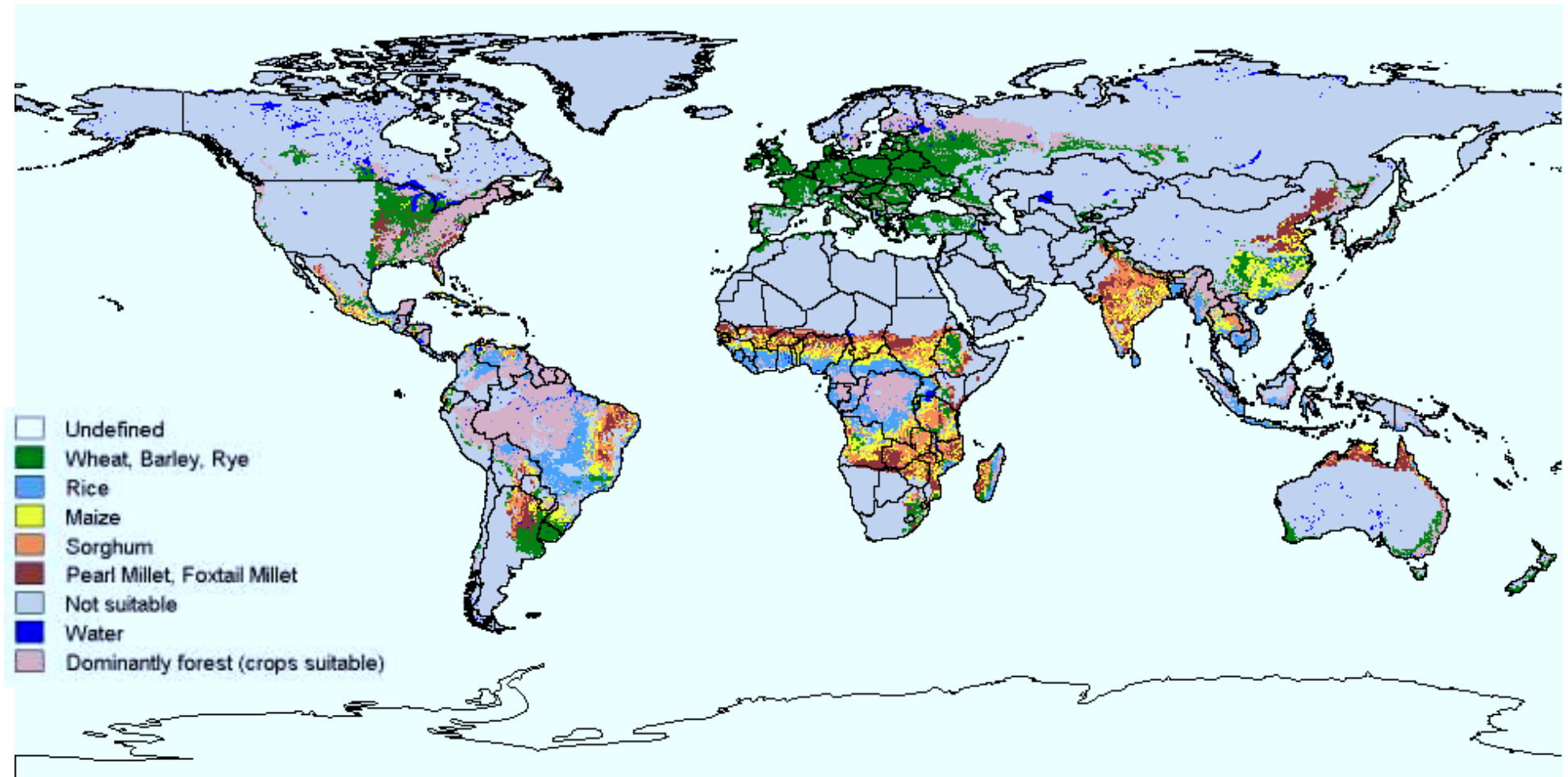


Plate 49. Most suitable cereal (food energy)

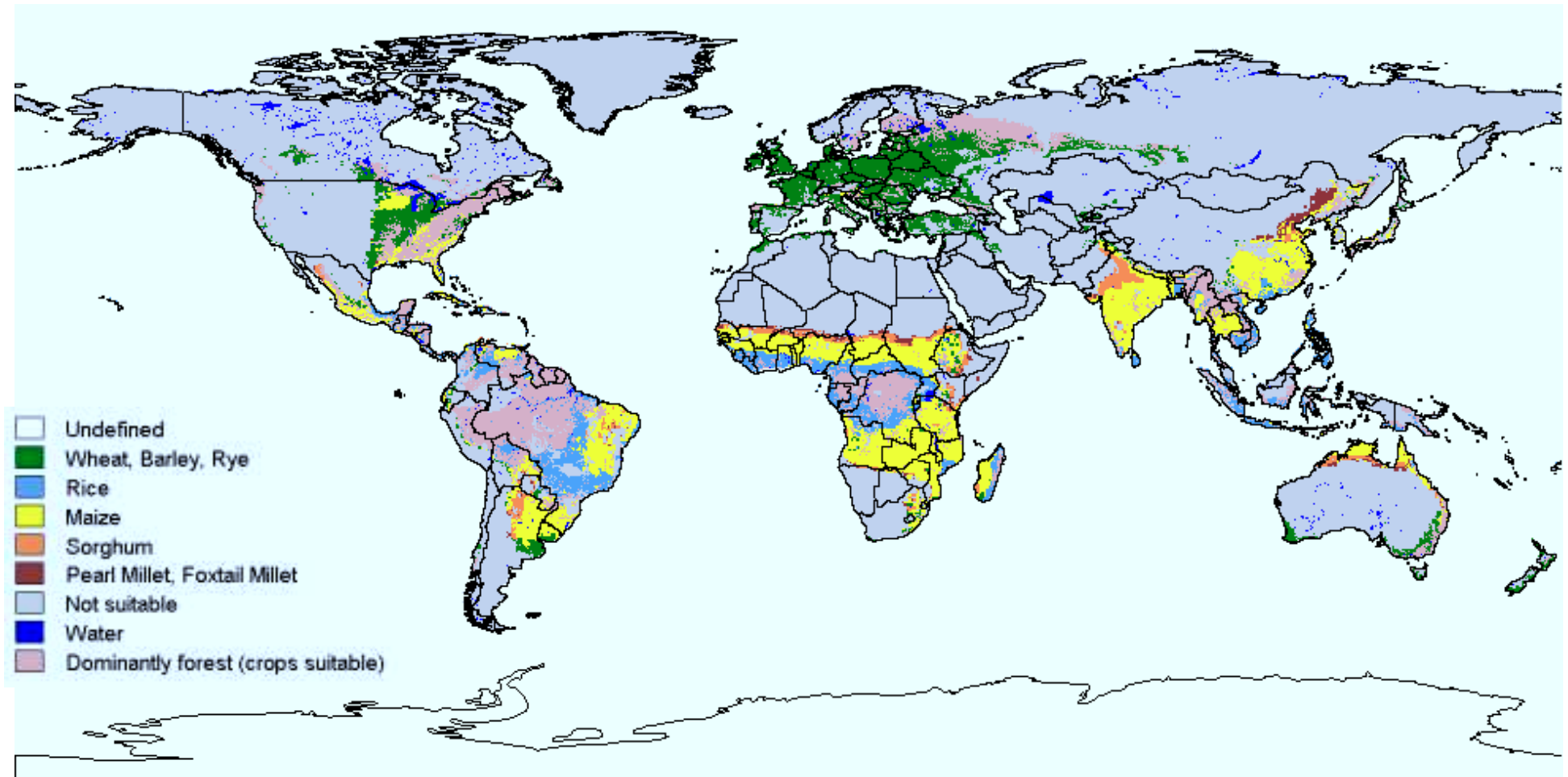


Plate 50. Most suitable cereal (output value)

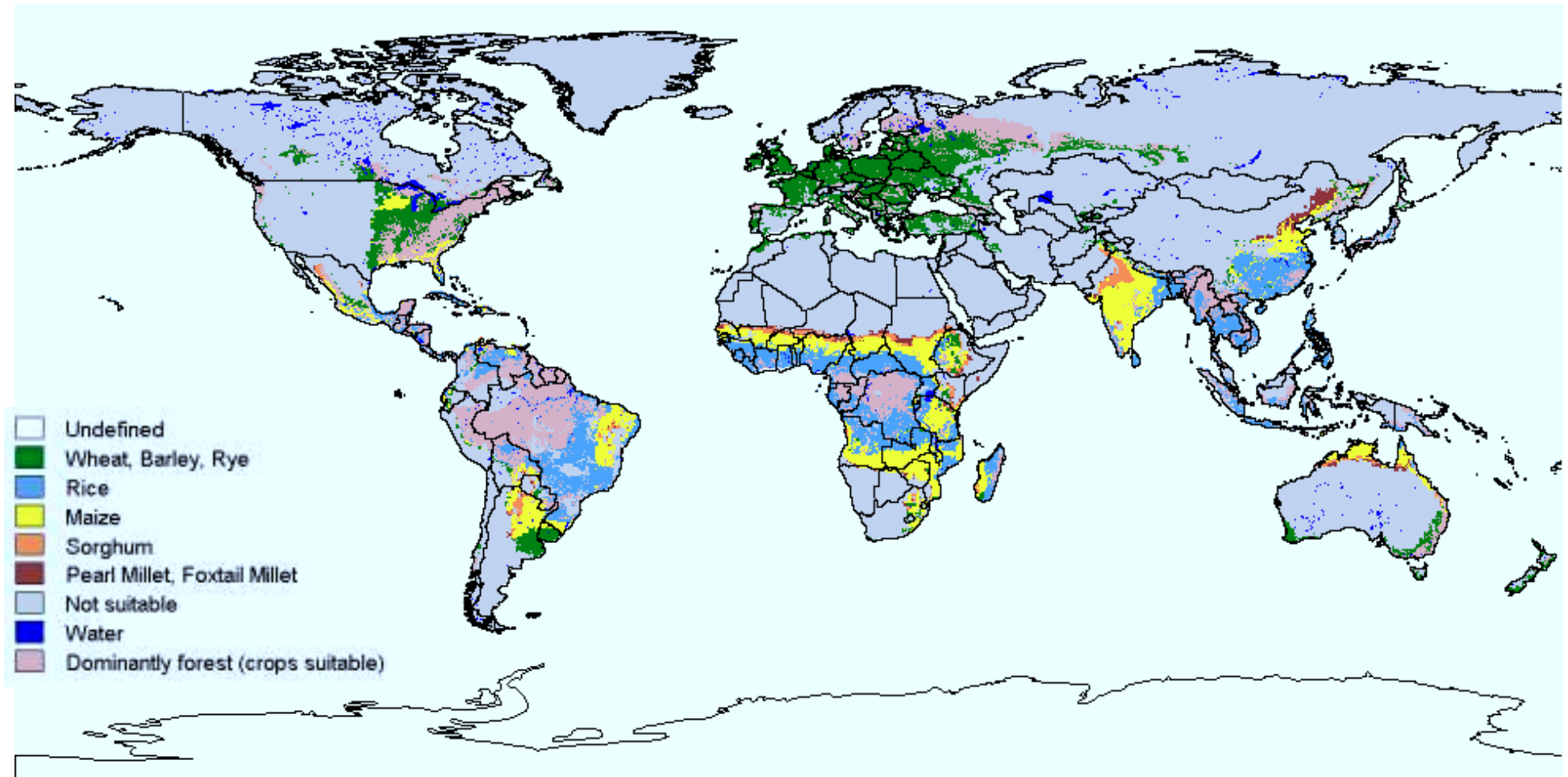


Plate 51. Expected grid-cell output per hectare for single cropping of rain-fed cereals (high inputs)

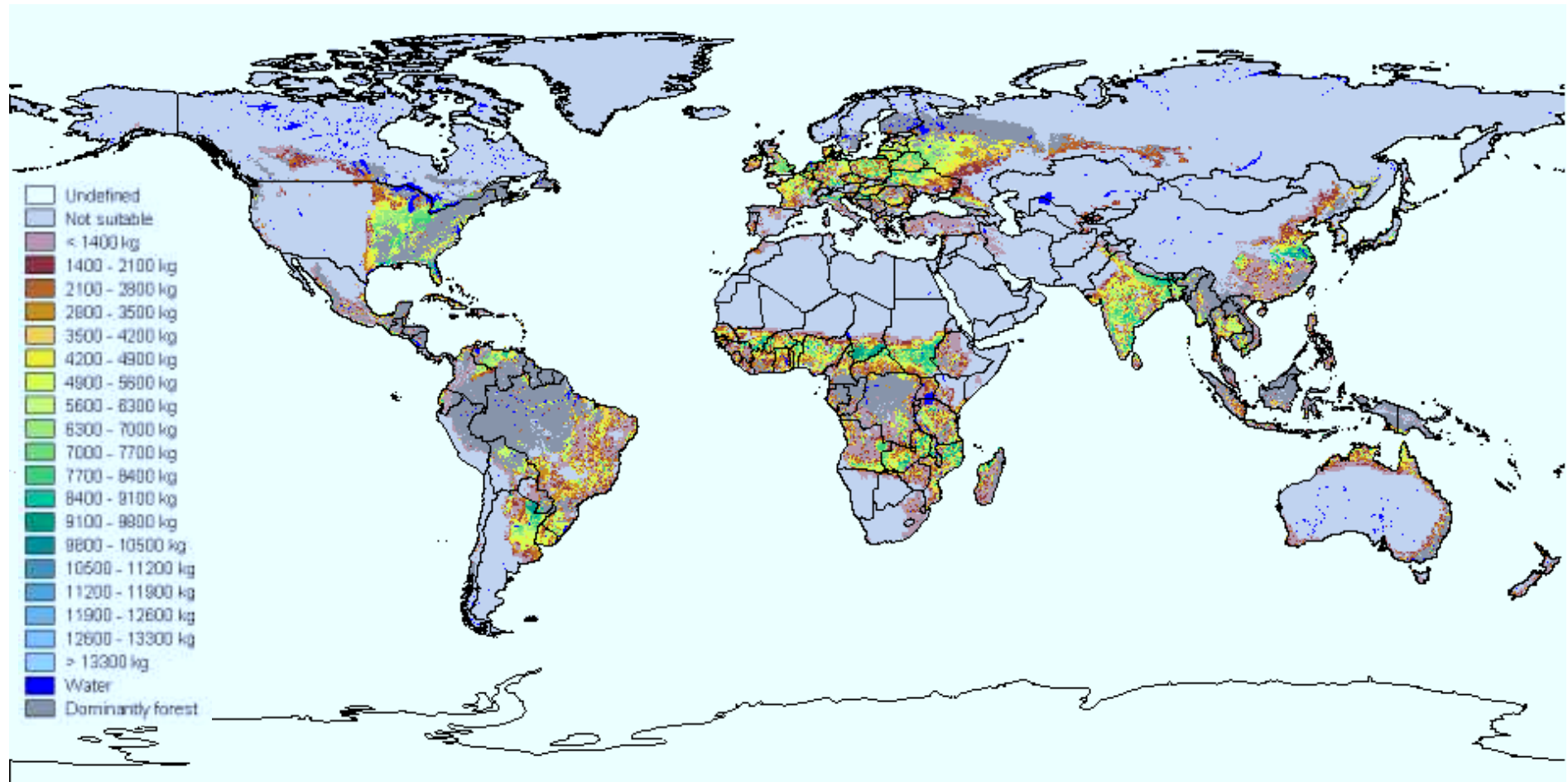


Plate 52. Expected grid-cell output per hectare for single cropping of rain-fed and irrigated cereals (high inputs)

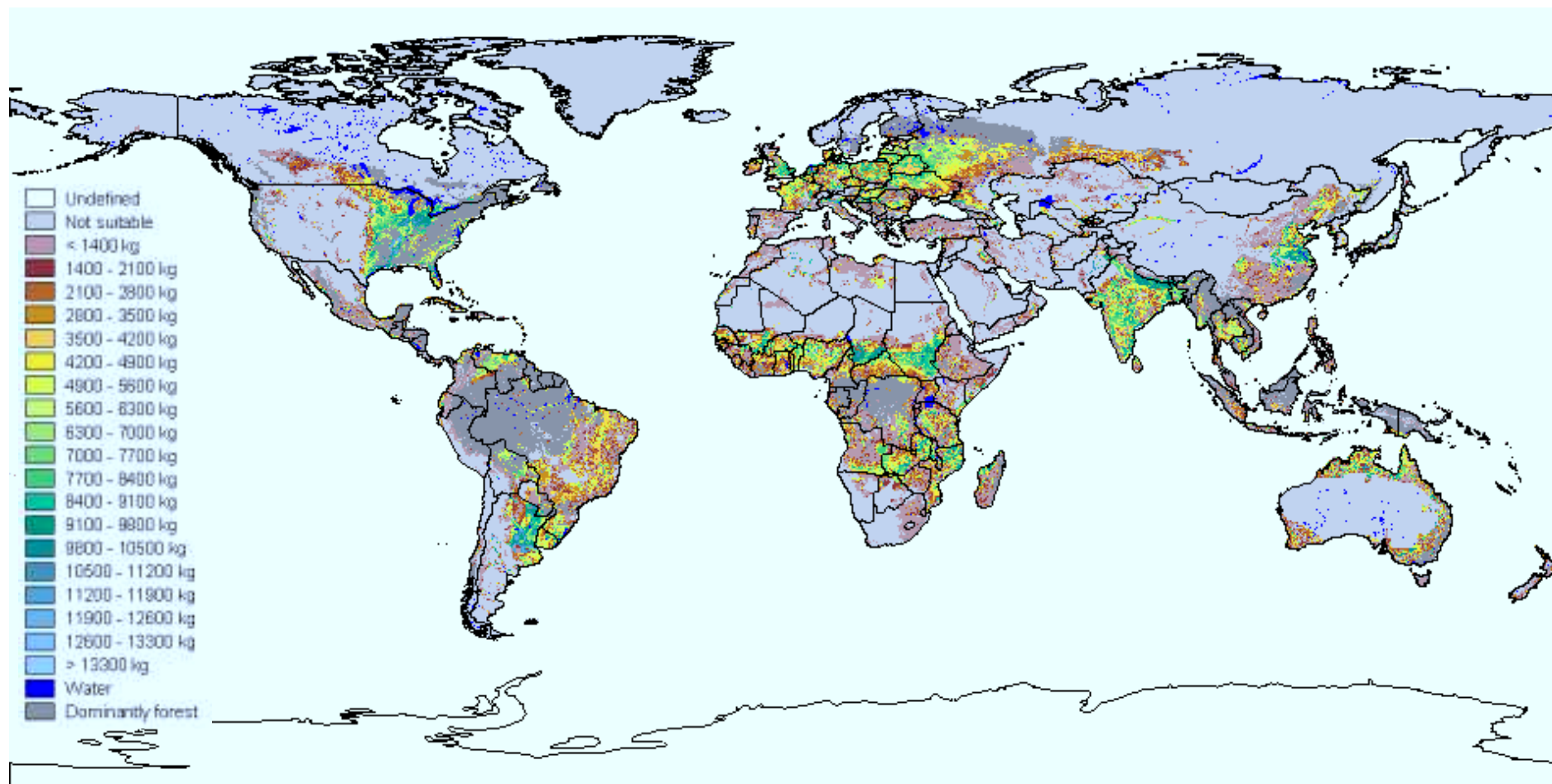


Plate 53. Expected grid-cell output per hectare for multiple cropping of rain-fed cereals (high inputs)

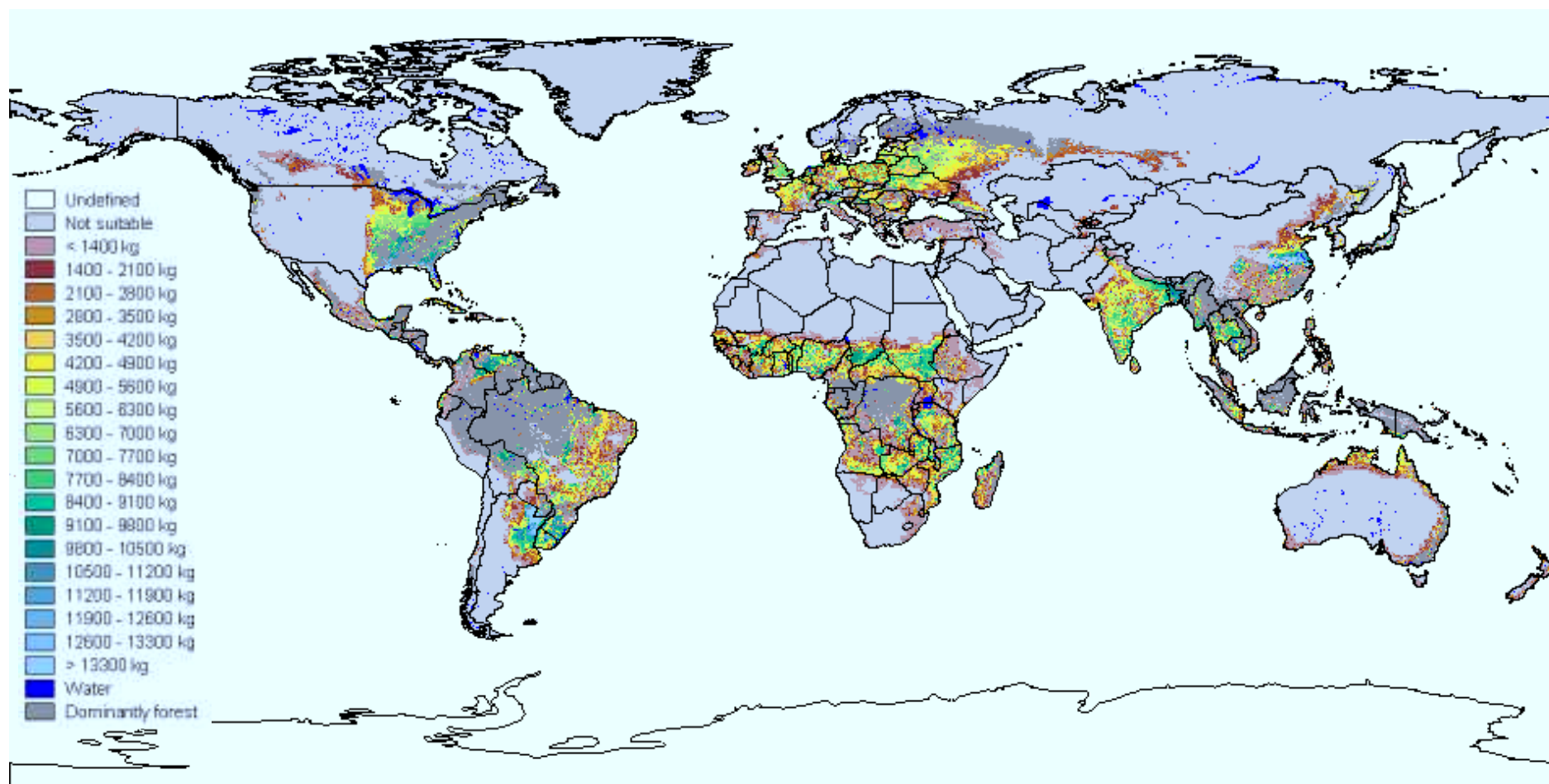


Plate 54. Expected grid-cell output per hectare for multiple cropping of rain-fed and irrigated cereals (high inputs)

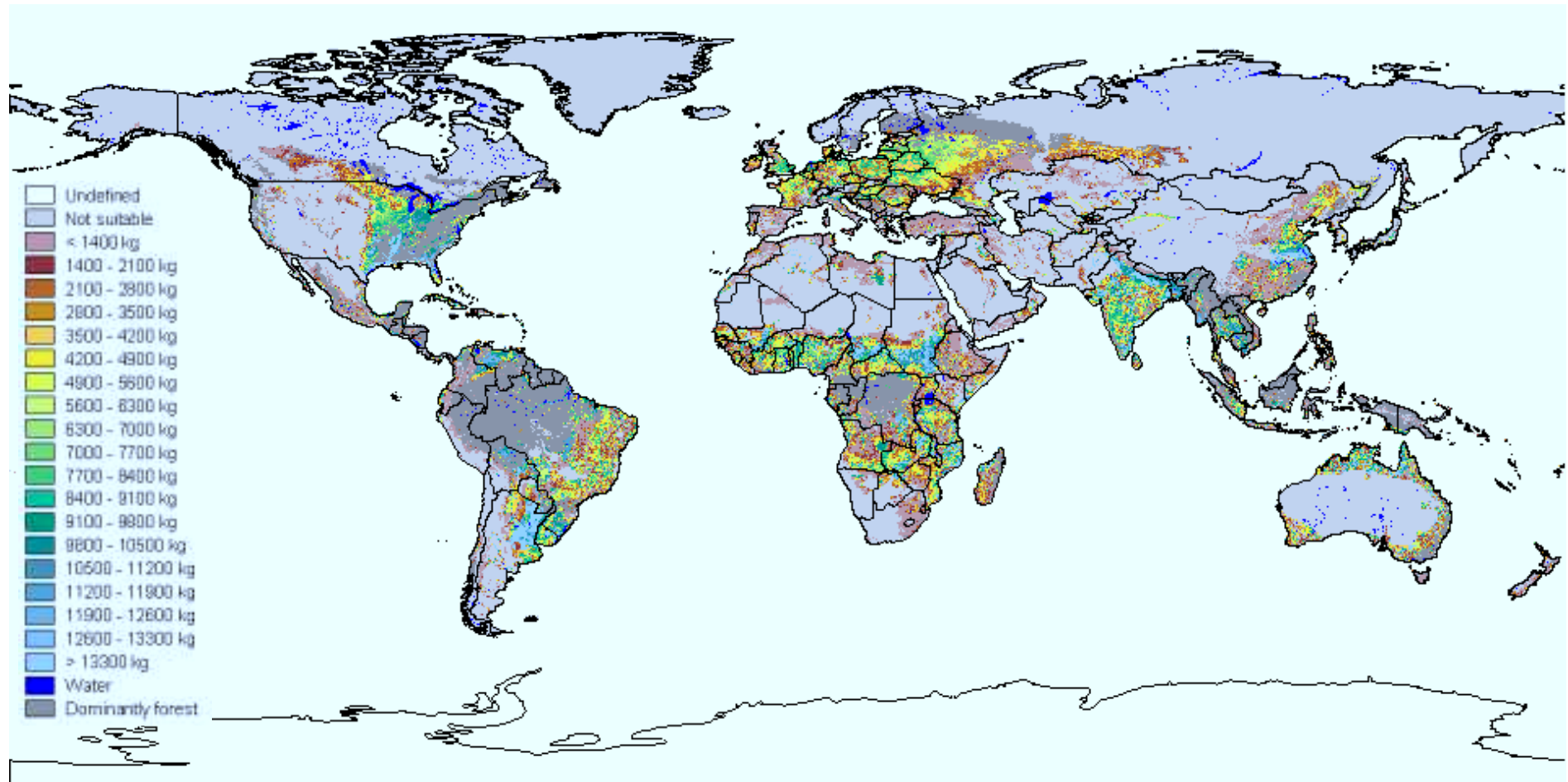


Plate 55. Dominant ecosystem classes

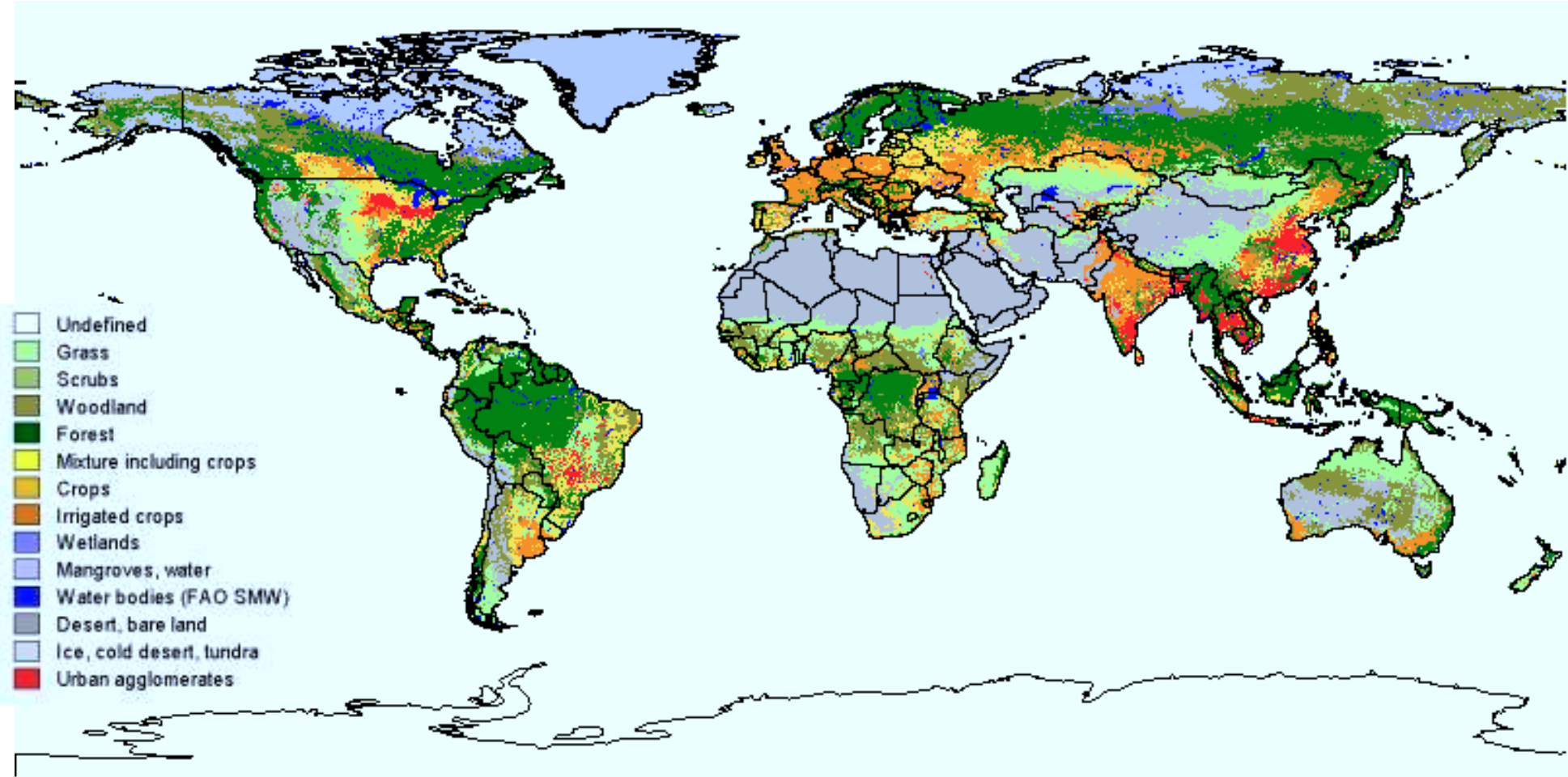


Plate 56. Suitability for rain-fed crops excluding forest ecosystems

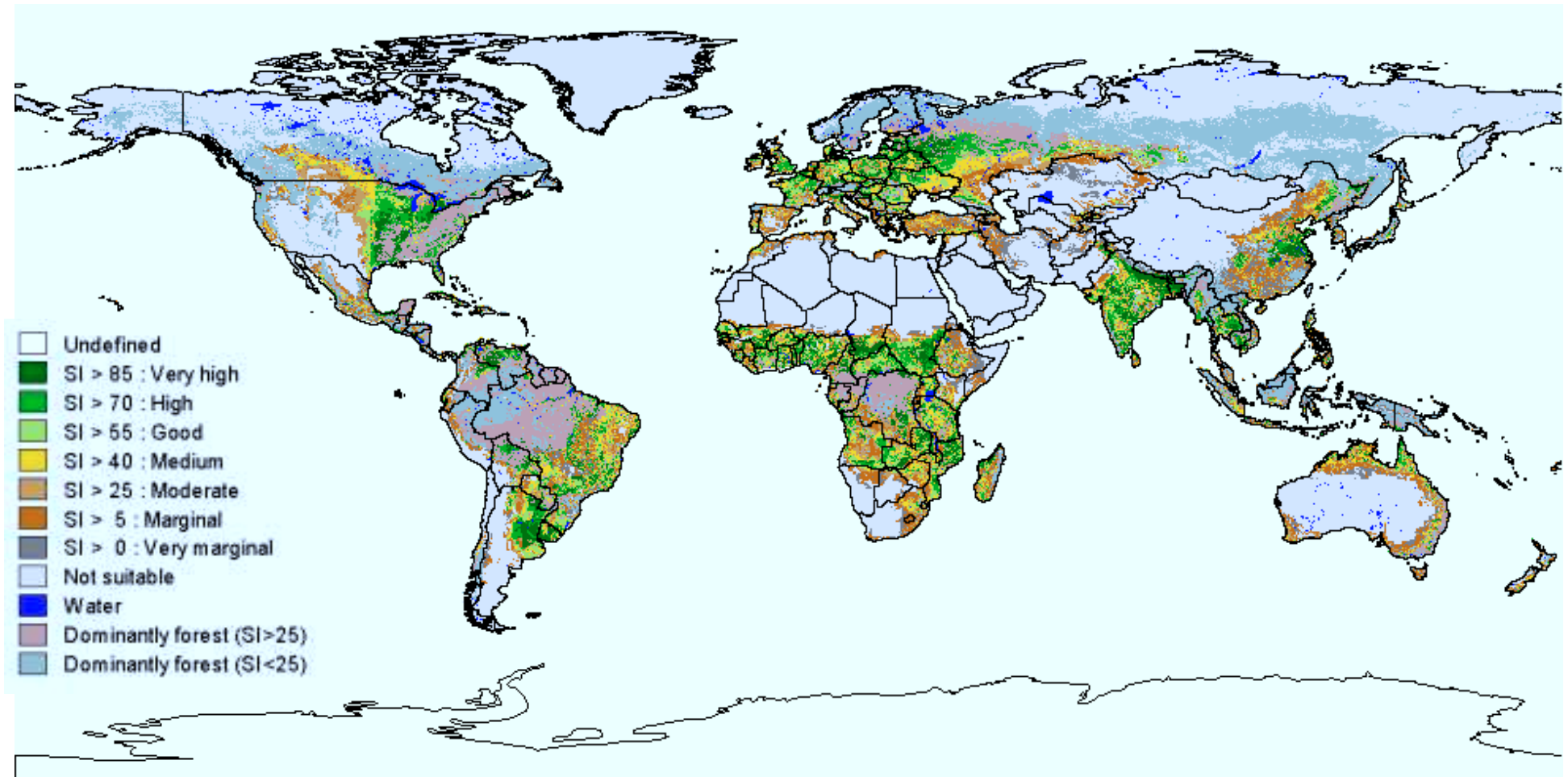


Plate 57. Suitability for rain-fed crops under forest ecosystems

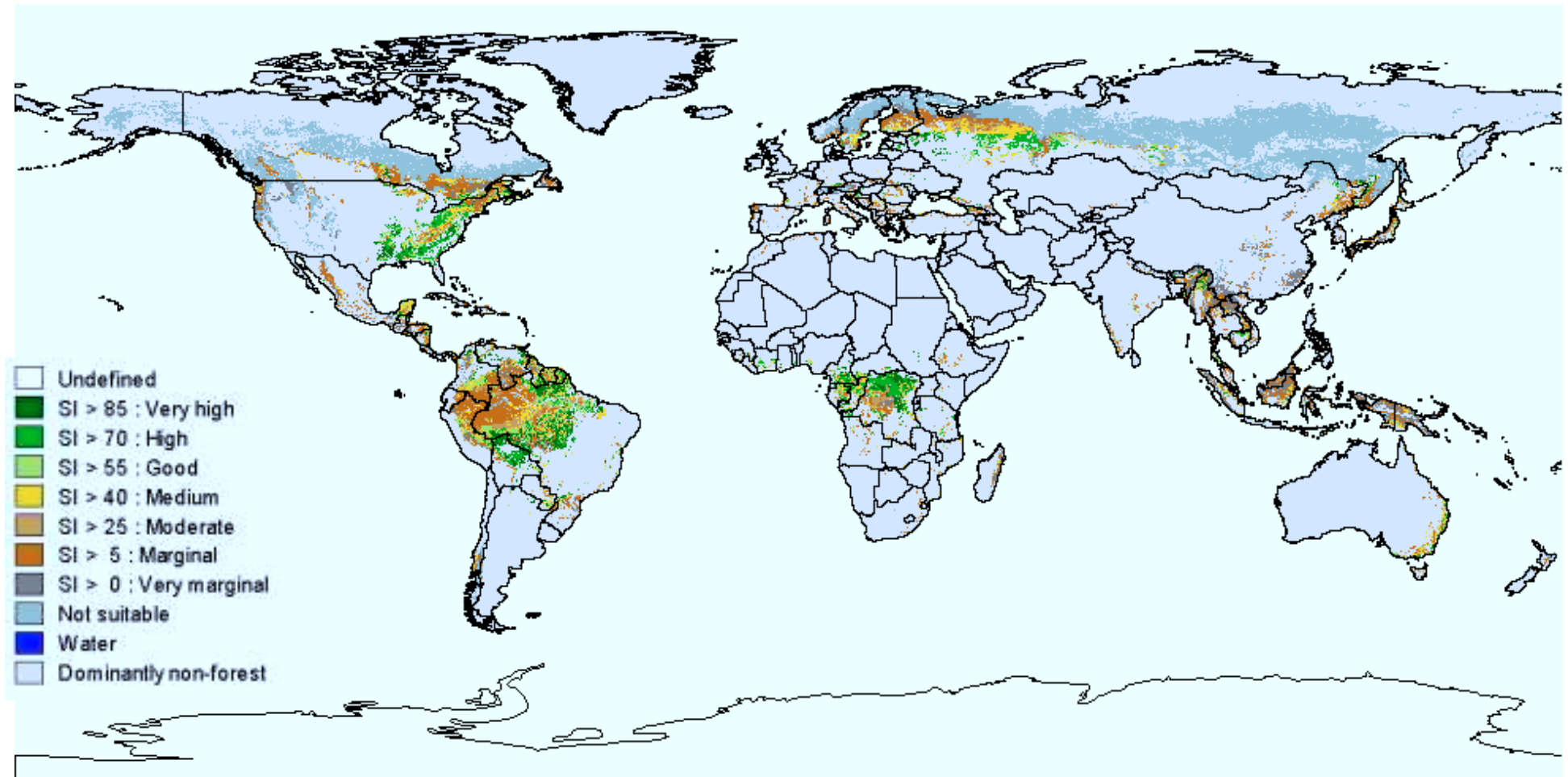


Plate 58. Change in number of growing period days at +2° C

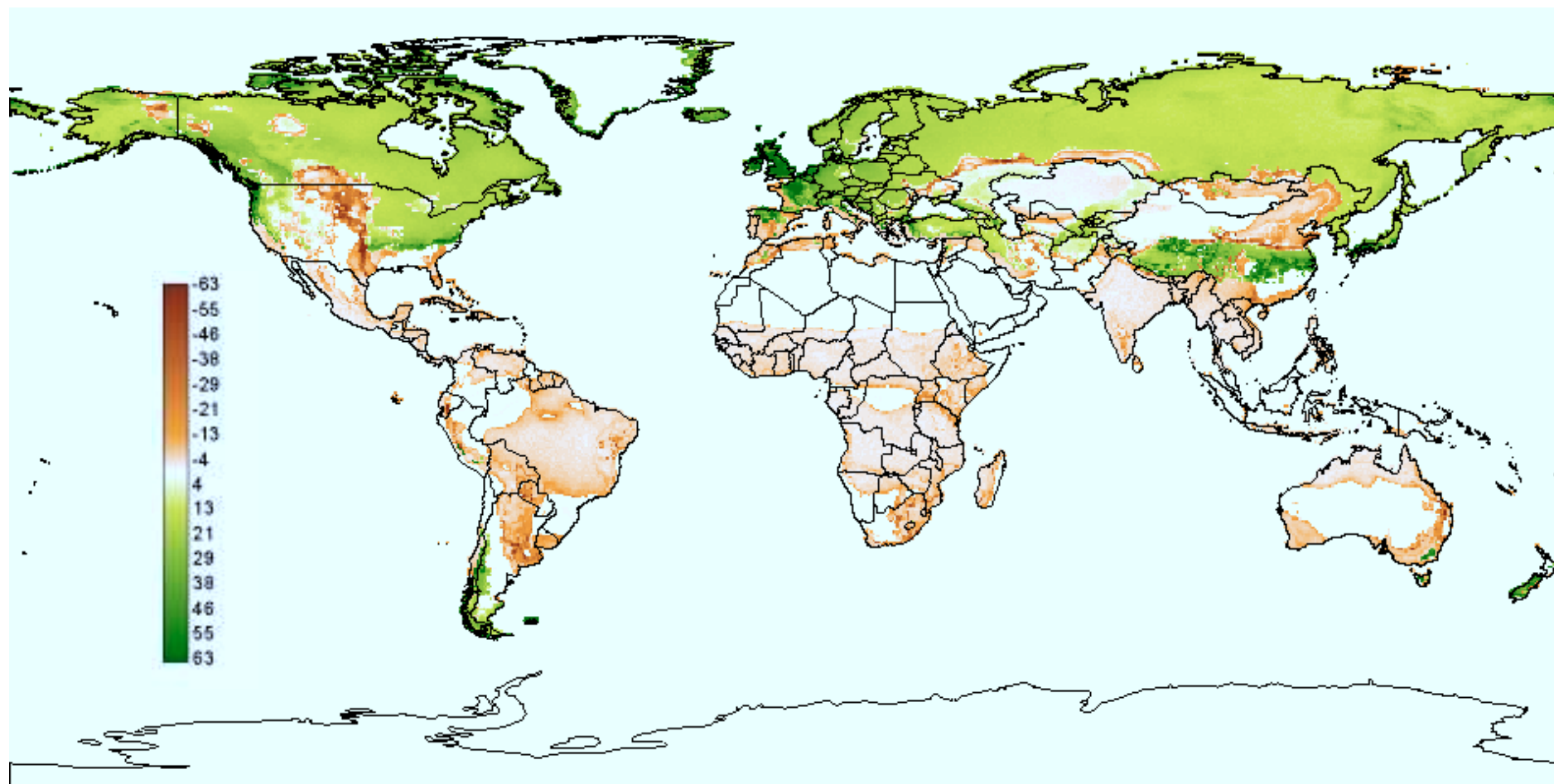
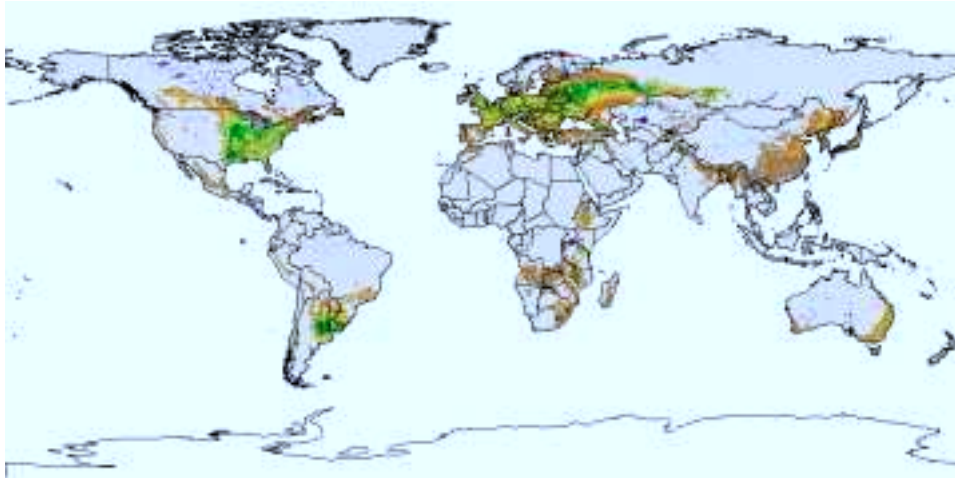
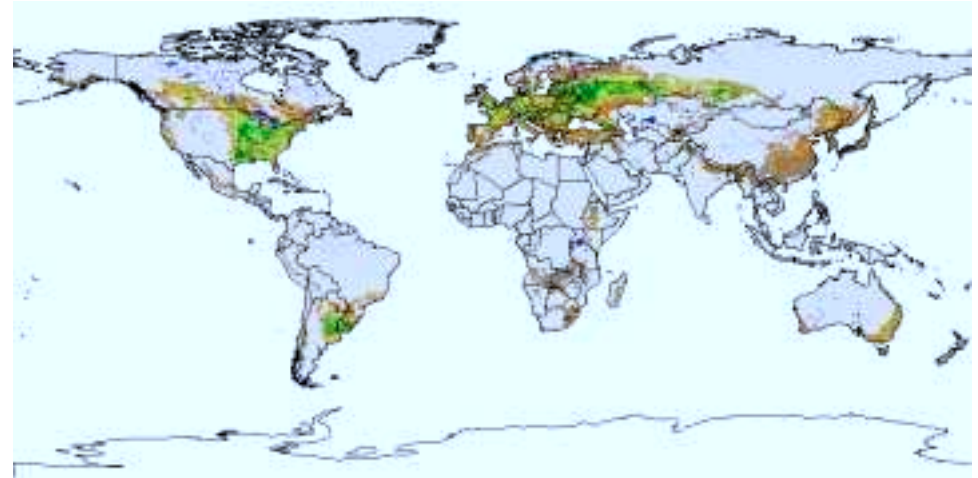


Plate 59. Climate Sensitivity: Suitability for rain-fed wheat (intermediate inputs)

Reference Climate



Climate sensitivity: +2°C



Climate sensitivity: +3°C, +10% precipitation

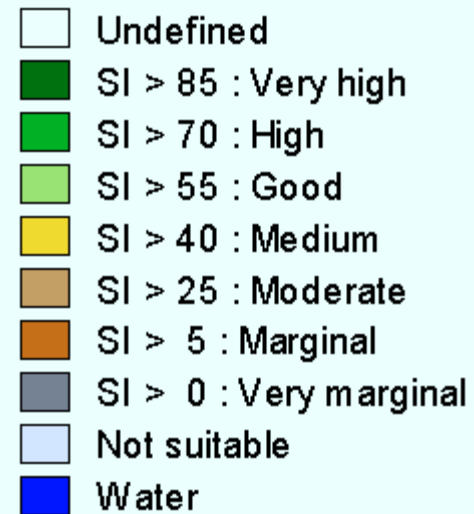
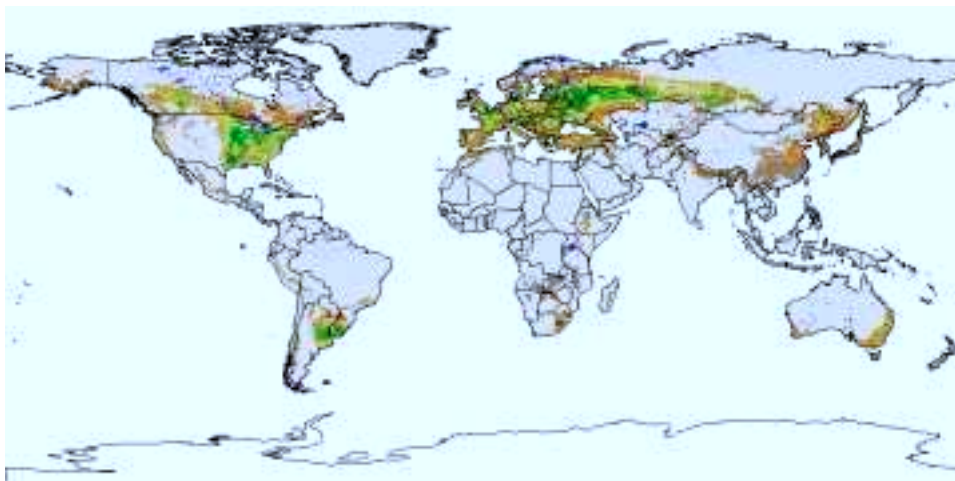
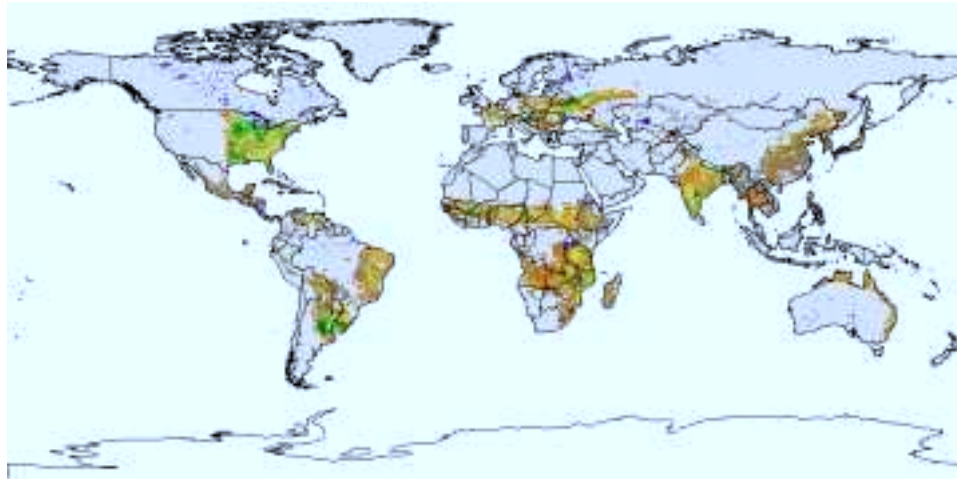
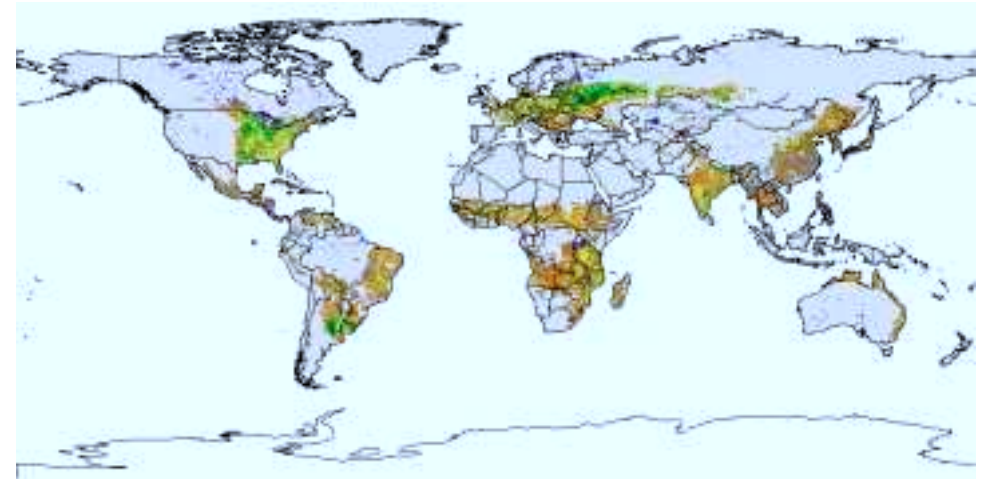


Plate 60. Climate Sensitivity: Suitability for rain-fed grain-maize (intermediate inputs)

Reference Climate



Climate sensitivity: +2°C



Climate sensitivity: +3°C, +10% precipitation

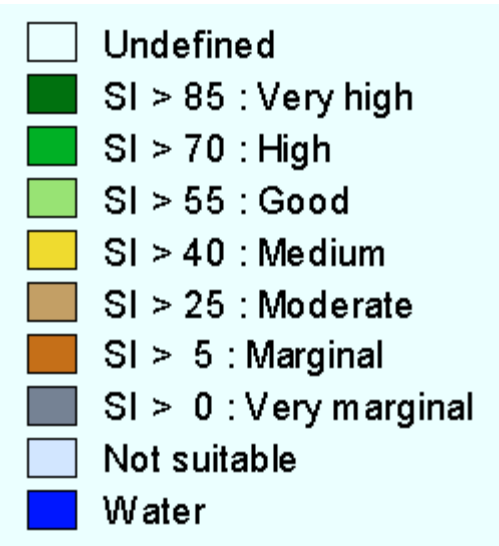
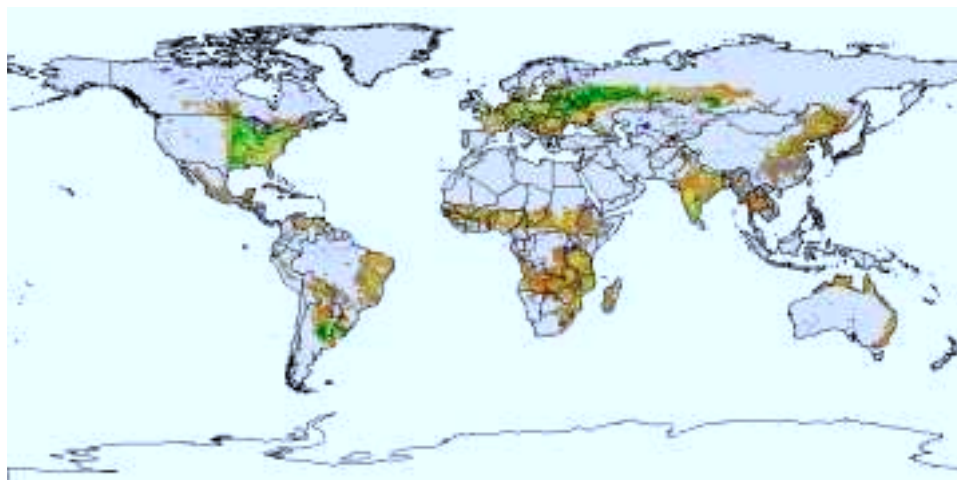


Plate 61. Regions used in global AEZ

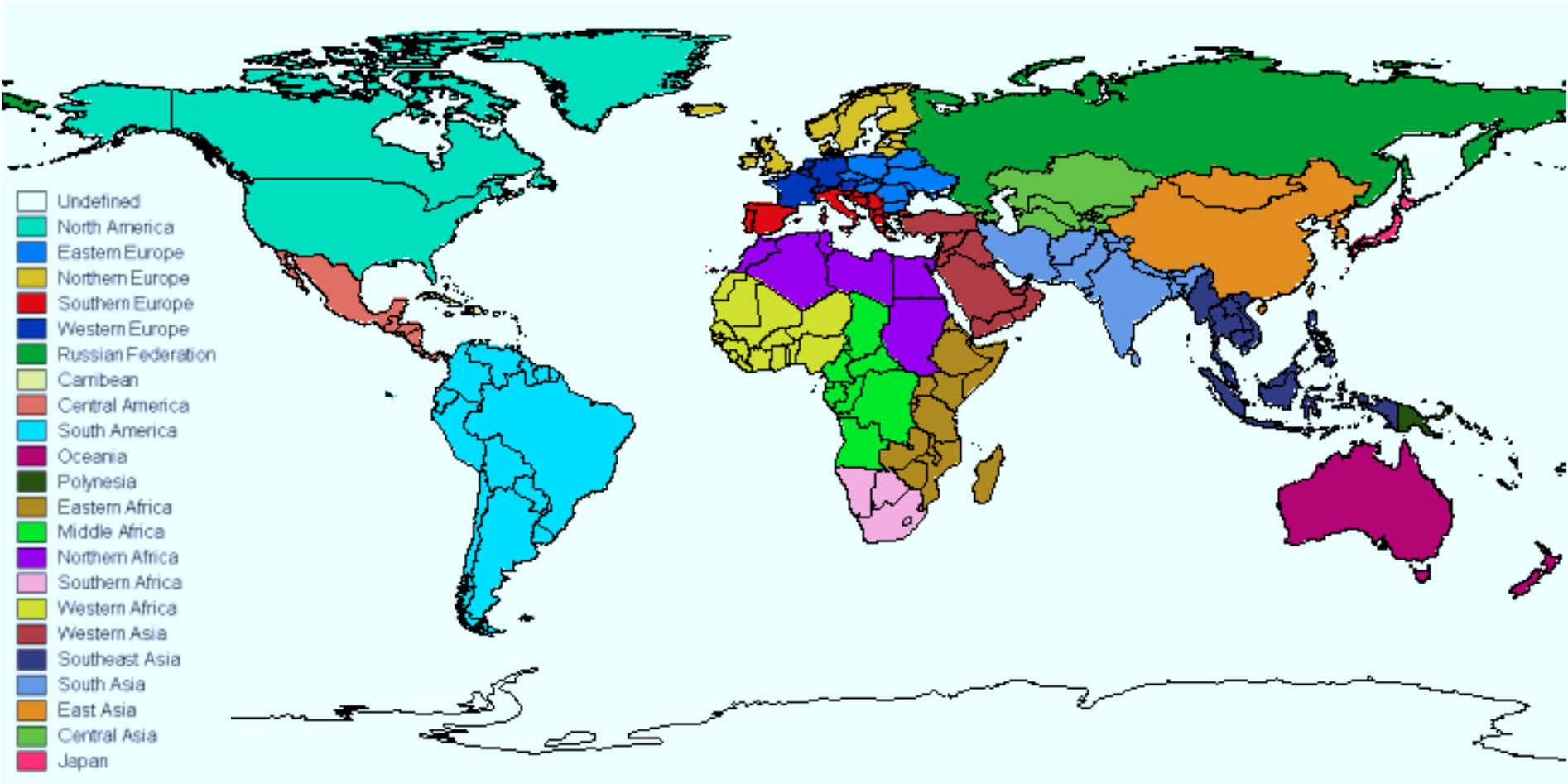


Plate 62. Population density in 1995

