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Land transformation, highly governed landscapes and landscape health: A case study of the Lower Piave area of northeastern Italy

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Land Transformation, Highly Governed Landscapes and Landscape Health:

A Case Study of the Lower Piave Area of Northeastern Italy

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Abstract

This dissertation examines the issue of biophysical landscape health. Its primary objective is to produce an interpretation of biophysical landscape health for the *highly governed landscapes* of the Lower Piave area of northeastern Italy. Highly governed landscapes are considered to be those which are highly controlled by humans to an even greater degree than normal cultural landscapes. An example is reclaimed agricultural landscapes such as those of the northeastern Italian coastal belt, from which the Lower Piave case study is drawn. These landscapes are *highly governed* because without constant human intervention, they would revert back to their former marsh state. The idea of landscape health is derived from ecosystem health, which is a metaphor drawn from human health. As with human health, a healthy system is one that is in a sound and complete state, and able to recover from distress and disease. "Health" concepts are increasingly viewed as more appropriate paradigms for measuring and assessing the state and condition of biophysical systems. The motivation for this research lies in the fact that traditional norms of land health (e.g. wilderness, climax) are not applicable to the unique biophysical and cultural nature of the Lower Piave.

An interpretation of biophysical landscape health is derived through a series of sequential research and analytical stages listed in Chapter 4. Stage one is a review of the conceptual basis of health from the fields of ecosystem health and integrity, sustainability and landscape ecology. Stage two is an investigation of the historical and cultural context of landscape governance through a landscape history of the Venetian Plain. Stage three examines 20^{th} century land transformation when the study area was reclaimed for agriculture, and thus transformed into a highly governed landscape. Further landscape transformation occurred with the modernisation of agriculture. Stage four consists of a detailed study of the nature and condition of key landscape elements in the Lower Piave. These elements include agriculture, land drainage, water quality and vegetation. Stage five identifies critical

landscape linkages and interrelationships. Stage six represents the interpretation of biophysical landscape health based on the integration of information from the previous steps.

The interpretation of landscape health consists of a general definition and a series of defining characteristics. Biophysical landscape health is generally defined as a condition where human governance sustains a landscape character and structure that is relatively stable over time, allows for balance between system components, is free from damaging human-induced distress and risk factors, and which maintains the ability of the landscape to provide ecological functions beneficial to humans and other organisms. Specific characteristics of landscape health include absence of distress and risk factors, sustainability, resilience, biological diversity, equilibrium and balance, and structural stability. Key to this interpretation is that a condition of landscape health is not incompatible with traditional land uses and landscape governance. This interpretation and defining characteristics is considered to be significant in that it represents a basic framework and starting point for landscape health monitoring and assessment. This definition is also significant in that it is considered to be applicable to other similar highly governed landscapes.

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Chapter 1: Introduction

The history of western civilisation has been characterised by increasing social, cultural and technological developments. Corresponding with these developments has been the progressive alteration of the earth's surface through resource exploitation and the creation of cultural landscapes. Cultural landscapes have been defined as landscapes whose attributes are largely the result of human influences and impacts. A common example is arable lands, where humans have essentially altered the composition of both vegetation and fauna (Vink 1983). Lands modified for agriculture are perhaps the most significant form of cultural landscape given the universal need to alter lands to create terrain suitable for crop growing. Other common forms of cultural landscape arising from human development include urban and suburban areas, which are the most "constructed" form of landscape.

Many, if not most, regions of the earth are now extensively cultural landscapes given the explosion of global population over the last two centuries. For example, Europe can be considered to be dominated by cultural landscapes as a result of centuries of civilisation. Agricultural landscapes are estimated to cover 80-90 percent of land in European Union (EU) countries (Paoletti 1993a). Cultural landscapes are now common given how human agency[1] has

[1]Carl Sauer introduced the term "human agency" in a landmark 1956 volume entitled: *Man's Role in Changing the Face of the Earth*. The general theme of this volume was the capacity of man to alter his natural environment, and the increasing appropriation of natural habitat as a result of the spreading of human culture over the course of human history. ***Human agency*** refers to the human practice of: "evaluating the economic potential of its inhabited area, and to organise its life about its natural environment in terms of the skills available to it and the values which it is accepted" (Sauer 1956). The consequence of this is that wherever humans live, they have worked to alter the biophysical characters of the earth, and in most regions of the world humans are the ecological dominants.

profoundly transformed the surface of the earth, and where humans continue to encroach on the few remaining areas relatively undisturbed by humans.

In keeping with the theme of cultural landscapes, and the human tendency and capacity to alter the biophysical landscape, this research concentrates on landscapes created by humans and how we view these landscapes in relation to the need to measure, assess and control adverse human impacts. This is an important issue given not only the increasing inability of the biosphere to absorb human impacts, but also the dominance of landscapes which no longer bear any resemblance to their state before even moderate human alteration. **In short, this dissertation identifies and investigates a particular type of cultural landscape created by humans, and focuses on developing a paradigm for investigating and assessing its state and condition.** The following sections of this introductory chapter outline the research problem in detail and identify the specific goals and objectives associated with this research.

1.1 RESEARCH PROBLEM

The idea of cultural landscapes and the need for appropriate paradigms to view these landscapes was briefly introduced in the preceding paragraphs. These two issues form the essence of this research. Stemming from these two broad issues is a number of concepts, which are fundamental to this research, including ***landscape***, ***landscape health*** and ***highly governed landscapes***. These concepts are now introduced along with the greater research problem this study seeks to address.

The Dutch first introduced the concept of *landscape* through landscape painting *(landschap)*. It gradually evolved from a mere indication of an area in space, to the character of an area in terms of its contents (Zonneveld 1989). In technical terms, a landscape has been defined as: "a kilometres wide mosaic over which particular local ecosystems and land-uses occur" (Dramstad *et al.* 1996). Another definition is: "a heterogeneous land area composed of a cluster of interacting ecosystems that are repeated in similar for throughout" (Forman & Godron 1986).

The term *highly governed landscape* is derived from *governed landscape*. A governed landscape is intended to describe a landscape that is constructed, guided and controlled by humans. The term "governed" was first used in reference to traditional northeastern Italian agricultural landscapes. It was used to describe the phenomenon where agricultural landscapes were subject to periodic interventions and manipulation by the subsistence farmer (Zanetti 1988). In this example, intense landscape interventions associated with agriculture were perpetuated over long periods of time in response to local environmental, economic and social conditions. The result of long term governance was the creation of an agricultural landscape with its own distinct cultural and landscape ecological conditions.

It must be emphasised that the idea of *governance* in this context refers to the physical manipulation of landscapes by humans and conscious efforts to create and maintain specific landscape characteristics. It does not refer to institutional, administrative or management mechanisms which are usually associated with the idea of governance. The term *governed* is preferred over other terms because it has been used within the specific cultural context of this study (northeastern Italy). Otherwise, it is possible that other common terms, such as manipulated, controlled, managed or organised, could also be used in its place depending on particular preferences and contexts.

A *highly governed landscape*, on the other hand, is considered to be a landscape subject to even greater degrees of human manipulation than a *governed* landscape. The example adopted for this research is land reclamation in coastal lowlands with particular emphasis on the reclamation projects undertaken in the northeastern Italian coastal zone. Reclaimed areas are called "highly governed" because they require the systematic and planned intervention of humans for their maintenance. In this case, the key distinction is that without a constant and intense degree of governance, in the form of controlled drainage, these cultural landscapes would revert to an entirely different biophysical state (a landscape complex of marsh, riverine and littoral ecosystems).

There are possibly many forms of highly governed landscape, especially those associated with intense agricultural use. It is emphasised here that northeastern Italian reclaimed landscapes represent only one form of highly governed landscape. Dutch polders and other sub-sea level reclaimed areas come to mind as similar examples of highly governed landscapes. Intensely cultivated terraced hillsides common to parts of Southeast Asia are another example, as are cultivation of desert areas through irrigation. Above all, the key characteristic of a highly governed landscape is an intense degree of human manipulation, which usually shapes or has transformed the biophysical character of the landscape. This is accompanied by the condition where the landscape would revert to an entirely different form in a relatively short time span without this manipulation.

The concept of *landscape health* has been adopted as the principal paradigm for this research. In preliminary terms, it can be understood as a broad measure of the state, condition or quality of the landscape. If the idea of *landscape health* is adopted, then the condition or state of the landscape can be defined by its "health".

The idea of health expressed in these terms, including its assessment and measurement, stems from the concept of *ecosystem health*. This in turn stems from the human practice of diagnosing and measuring human health through medicine. According to the ecosystem health view, an ecosystem state or condition can in many ways be considered analogous to human health. As with human health, ecosystem health is a holistic concept concerned with the state or function of a biologically based system. It has been described as the absence of detectable symptoms of ecosystem disease, pathology and malfunction (Rapport 1989a), or something in a sound, complete, and unimpaired state (King 1993). A healthy ecological system is one which is active, stable and sustainable, and able to maintain its self-organisation and autonomy over time (Costanza 1992a).

The premise of this research is that concepts of "health" have potential applications to highly governed landscapes because nature, or what is "natural", does not have to be in a pristine state in order to be judged as "healthy". This is important because landscape conditions in northeastern Italy, for example, scarcely resemble the "pristine"[2] landscape complex which emerged after the most recent period of glaciation.[3] Furthermore, the ecological conditions in highly governed landscapes do not fit popular notions of nature (e.g. pristine or untamed wilderness, climax or "virgin" forests). Therefore, the general thrust of this thesis is to develop a concept of landscape health applicable to highly governed landscapes. **More specifically, this research seeks to more thoroughly explore and develop the concept of landscape health as a useful and practical paradigm for *highly governed landscapes*.**

While the idea of landscape health, or the conditions which ensure landscape health, provides the thrust for this research, another significant point of interest is the fact that this is done within the context of a landscape that has been subject to a number of culturally-induced land transformations. The northern Italian plain and its coastal lowlands provide the backdrop for this study. The northern Italian plain is extensive lowland created by the alluvial deposits of the large number of rivers flowing into the region from the surrounding Alps and Apennine mountain areas. Prior to technological developments of the modern era, agricultural landscapes had been sustained for centuries on large parts of this fertile and humid plain using subsistence agricultural practices. However, 20th century technological development and industrialisation resulted in the decline and

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[2] Pristine in the sense of the landscape not having been altered by intense human activities such as agriculture and widespread settlement..

[3]See Chapter 3.

elimination of many of these traditional landscapes as well as the creation of new agricultural landscapes through land reclamation in coastal areas.

During the early 20th century, the Italian government initiated a series of ambitious land reclamation projects along coastal wetland areas in order to expand agricultural land and to eradicate malaria, which constituted a severe health risk. The result was the creation of new agricultural landscapes. Perhaps the most striking feature of these new landscapes, as compared with traditional Italian agricultural landscapes, was that they could only be created and sustained on a large scale with mechanised drainage as these areas were at, or very close to, sea level. In other words, these landscapes depended on the perpetual maintenance of mechanised drainage schemes, which only became viable on a large scale during the 20th century. Hence, these landscapes are *highly governed* in the sense that they are subject to even greater degrees of human manipulation compared to traditional rural agricultural landscapes of northeastern Italy.[4]

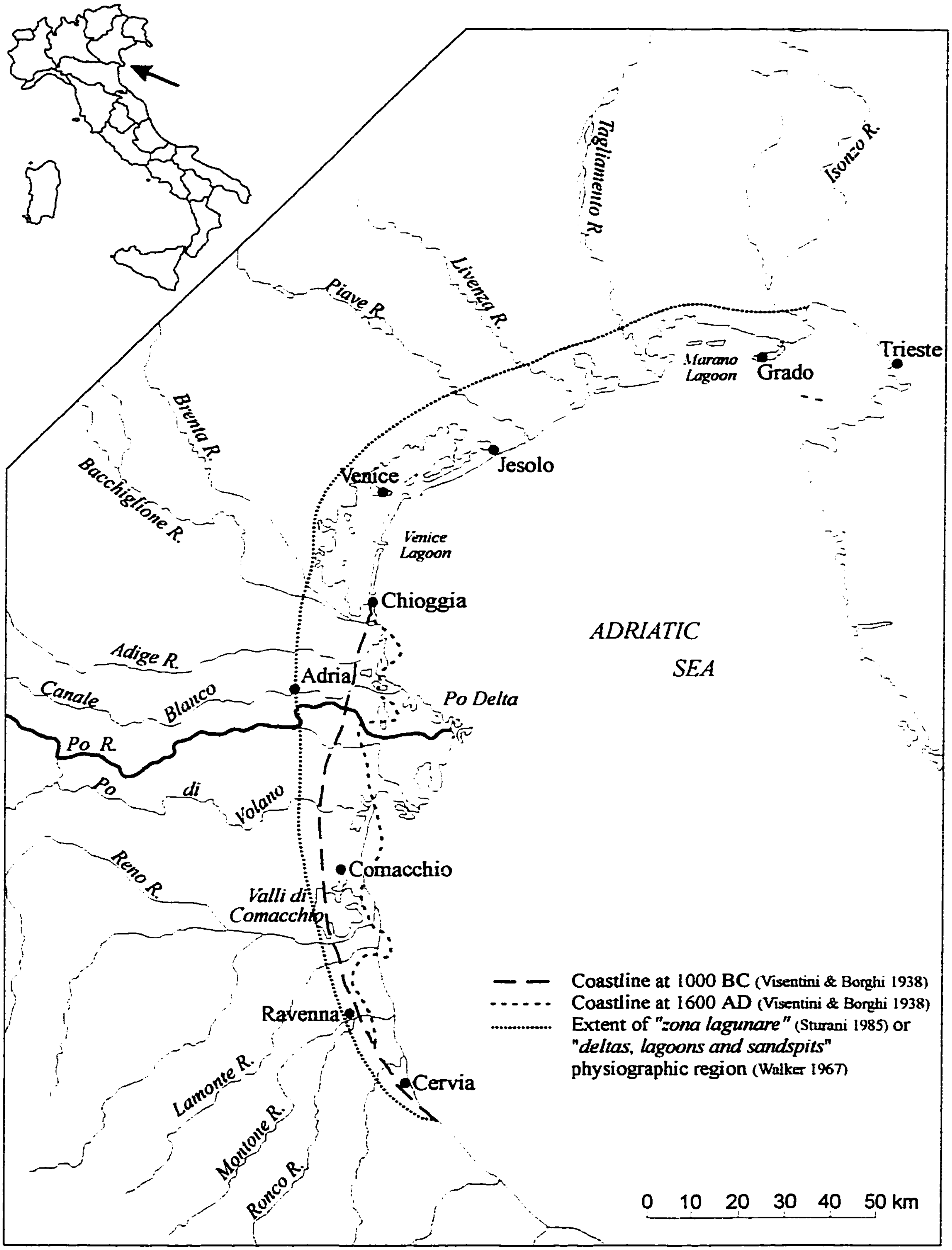
One of the areas subject to extensive land reclamation during the early 20th century, and which is the focus of this case study, is the eastern coastal margin of the northern Italian plain. This area is shown on Map 1.1 on the next page. In prehistoric times, this coastal margin was characterised by a belt of marshes and lagoons separated from the Adriatic Sea by a cordon of dunes, sand spits, and sandy beaches. These continuously changed due to deposition and erosion from rivers, sea currents and tides.[5] Portions of this coastal and near coastal area, especially along the lower courses of major rivers[6], have been targeted for agricultural reclamation since Roman times with widespread reclamation occurring since the turn of the century. Furthermore, most of the region's rivers and watercourses have been diverted, channelled or leveed over many

[4]A description of traditional Venetian landscapes and agriculture follows in Chapter 3.

[5]This statement is almost universally accepted in Italian academic circles. See Bondesan *et al.* (1995), Pirazzoli (1991) and Ortolani (1967).

[6]The area adjacent to lower courses of rivers was usually slightly higher than the surrounding marsh lands because of regular sediment deposition along banks of rivers (Bertolini & Rinaldi 1934; Bondesan *et al.* 1995)

Map 1.1: Northeastern Italian Coastal Zone



Base Map reproduced from Touring Club Italiano (1986)

centuries to facilitate drainage and protect reclaimed and low lying areas from flooding.

Today, most low lying and marshy areas have been reclaimed and the landscape is characterised by a grid of artificial drainage networks, flat farm fields, settlement nodes, and some larger urban concentrations. The advent of mass tourism in the post World War II years completed the transformation of the coastal zone. As beach tourism and recreation became popular, recreational facilities and urban development proceeded along the most favourable stretches of waterfront to create a heavily urbanised and developed coastline.

As the focus of research into landscape health, highly governed landscapes created from land reclamation in Italy are significant for a number of reasons. One is that these unique landscapes will continue to be highly governed in the foreseeable future given they have absorbed extensive urban settlement and coastal tourism development since original reclamation. It should be noted that settlement occurred despite the perpetual flood risk that afflicts these coastal lowland areas. Furthermore, the governance of these areas rests upon the maintenance of mechanised drainage systems, which entail considerable economic costs. Human control of drainage adds another dimension to land governance and is another reason why a reclaimed agricultural landscape is considered to be a *highly governed landscape* rather than merely a governed landscape or another form of cultural landscape.

Another significant factor is that these reclaimed agricultural landscapes have undergone further radical change with the post World War II transformation of Italian agriculture from a predominantly subsistence form to its current modern form. This phase of environmental change has brought about a number of significant consequences from a "health" point of view. These consequences will be identified in later chapters when landscape change and its consequences are examined in detail.

The final point of significance is that different phases of environmental change, combined with existing forms of land governance, have created a landscape context which is not easily served by existing notions of health or existing environmental management paradigms. These include traditional notions of "preservation", "conservation" or even *sustainability* - a concept that will be examined in greater detail in the next chapter. Popular notions of land health as pristine wilderness (Callicott 1992), or even the traditional view of the climax vegetation state, are not applicable in this case. Furthermore, assessment of a landscape's health based on a comparison with the original ecosystem is also irrelevant given the elimination of the former marsh landscape complex.

There is also the question of how these landscapes should be managed or governed. For example, what landscape processes features or ecological resources should be conserved? How do we manage for sustainability or health when these highly governed landscapes differ from more conventional agricultural landscapes because of the element of drainage control?

In short, there are many questions associated with these landscapes from both "health" assessment and landscape management perspectives. The premise is that the highly governed nature of this landscape, which is largely based on the element of drainage control, requires it own perspective of "health" compared to other landscape forms including less governed agricultural landscapes. **Thus, the key question to be resolved is how we view the health of a landscape that is the product of two distinct transformations, and which does not fit conventional paradigms of how we monitor and assess the biophysical state and condition of landscapes.**

1.2 SCOPE OF THE STUDY

While the general thrust of the thesis is to explore the issue of landscape health, the specific scope of the research can be captured by two sequential questions; the second of which forms the unifying goal of the research. Namely:

- **What are the conceptual, cultural, and ecological bases of "health" for the highly governed landscapes of the Lower Piave area of northeastern Italy?**

- **How can a concept of *biophysical landscape health* be interpreted for this area given these bases and existing landscape processes, and what are parameters for its measurement?**

These two research questions also correspond to the principal components of this research. The first question concerns the investigation of conceptual, cultural and biophysical aspects of "health" in this particular context. This forms the investigative and analytical portion of the dissertation. The second question relates to the integration of these to develop a definition or interpretation of biophysical landscape health. This includes a conceptual definition relevant to the environmental and cultural conditions in the Lower Piave; followed by a set of characteristics or criteria, which can be used to measure for, and assess landscape health.

Resolution of the first question has been broken down into four specific research stages. These stages provide the basis for interpreting landscape health, and consist of:

1) Review of the conceptual basis of the idea of "health" as it relates to landscapes, including the review of attempts to quantify and assess health.

2) Investigation of the historical and cultural context of landscape manipulation and governance in the Lower Piave, with particular emphasis on the cultural and environmental aspects of the great land transformations of the 20th century.

3) Description and analysis of key biophysical and cultural landscape elements in the Lower Piave with an emphasis on the comparison of their condition between the pre-modern and modern era.

4) Identification and description of the linkages and interrelationships existing between the key cultural and ecological elements of the highly governed landscape.

The first stage encompasses the investigation of relevant and contemporary conceptual paradigms concerned with investigating and assessing landscape conditions. An investigation of related ideas provides the initial theoretical base. This is followed by examination of historical landscape change and crucial 20th century landscape transformations, which created the highly governed landscapes under investigation. This stage also includes the examination of cultural elements driving landscape change and transformation. This stage is followed by the analysis of key landscape elements and important linkages and interrelationships between landscape elements. The strategic goal of developing a meaningful interpretation of biophysical landscape health involves the integration of information from these four stages.

Along the lines of this framework of research goals and components, the dissertation has been organised into an 8-chapter format. ***Chapter 2*** consists of a basic review of theory related to the issue of "health" as it pertains to landscapes and biophysical systems. The field of ecosystem health, the concept of sustainability, and the discipline of landscape ecology are reviewed for what they can contribute to developing biophysical landscape health. ***Chapter 3*** introduces and describes the Lower Piave study area and the surrounding Venetian Plain. This chapter emphasises the historical and cultural development of Venetian landscapes. The objective is to outline the cultural context of landscape governance and set the stage for detailed analysis of 20th century landscape transformations in Chapter 5. This chapter is important as past historical and cultural developments have not only influenced 20th century transformation, but also have a bearing on contemporary landscape health. It is also considered invalid to interpret landscape health outside of local historical and cultural parameters. ***Chapter 4*** outlines the methodology employed for resolution of the primary research goal. This includes a more thorough description of the 4 stages outlined earlier. ***Chapter 5*** describes 20th century landscape transformations in the Lower Piave. This is a crucial chapter as during this era, the Lower Piave became a *highly governed landscape* and was further transformed in tandem with the modernisation of agriculture. **The highly governed landscape created by initial reclamation is the reference point for the analysis in Chapter 6 and the focus of biophysical landscape health in Chapter 7.** ***Chapter 6*** contains the analysis of key landscape elements in the 20th century highly governed landscape. The objective of this chapter is to identify the state and condition of landscape elements from a "health" perspective. The emphasis is on their evolution from the "pre-modern", or early 20th era, to the post W.W. II "modern era". This chapter also provides the basis for identifying crucial landscape linkages in Chapter 7. ***Chapter 7*** consists of the integration of historical-cultural, conceptual, and biophysical analysis to produce a suitable interpretation of biophysical landscape health for the Lower Piave area. ***Chapter 8*** provides summary and concluding comments regarding research.

1.3 STUDY BOUNDARIES

In a general sense, this research is about developing a concept or paradigm suitable for evaluating or assessing the "health" of what are called *highly governed landscapes*. In itself, this is an ambitious, complex and multi-faceted task. The scope of the problem has been narrowed down by the specification of a single unifying goal and a series of research stages. The problem is further narrowed by the selection of a specific study area known as the Lower Piave (introduced in Chapter 3).

However, the broad issue of landscape health comprises a number of different aspects. Furthermore, there are also many disciplinary frameworks available to conduct an investigation of this nature. Even the selection of a single disciplinary framework to conduct this study is no simple task as there are different approaches within specific fields and disciplines themselves. This section therefore seeks to more clearly define the focus of this study by specifying study boundaries concerning disciplinary and conceptual approaches, and specific contextual issues. This will also clarify why certain issues have been omitted in the discussion and conceptualisation of landscape health.

1. Contextual Limits to the Study

By definition, highly governed landscapes are created and controlled by humans. As they are cultural landscapes, the issue of their quality or "health" should normally encompass both biophysical and cultural elements of landscape. Cultural elements of landscapes include a range of concrete elements including human populations and settlements, human activities and economic sectors, and human organisational aspects such as government and other institutions which guide and control human activities on the landscape. It is appropriate that a comprehensive landscape health paradigm should include cultural elements of "health", given humans are an integral part of the landscape.

Given the above consideration, it is emphasised that this research is primarily concerned with **biophysical** aspects of landscape health. Cultural considerations play an important role in this research, such as with the fact that biophysical landscape health must accommodate existing land uses and patterns of human landscape governance (e.g. intensive agriculture and intensely managed drainage). However, in order to narrow the study's focus, important issues such as human health, community health, and economic health are not considered in any depth. The only cultural element given extensive treatment is the practice of agriculture. This is because agriculture is the dominant human activity and exerts a huge influence on biophysical landscape health.

The omission of other cultural elements is not intended to diminish the importance of these factors, except that a comprehensive investigation including all possible dimensions of landscape health is a massive undertaking. Given time and resource constraints, these aspects are omitted. As a consequence, characteristics of landscape health proposed in Chapter 7 primarily emphasise biophysical conditions necessary for landscape health.

Furthermore, institutional and management aspects of health are not considered in this research. The cultural component of landscape also includes a variety of government institutions, which have been developed over time to organise and order human activities. This also includes contemporary institutions responsible for general environmental planning and management. In addition to past roles in shaping landscapes, government and bureaucratic institutions have a large role to play in landscape management and landscape rehabilitation. Although significant and important to the issue of landscape health, institutional aspects are also omitted from consideration to keep the study within manageable limits. The exception is the brief description of the Italian State's role in reclamation, which provides important historical information on landscape transformation.

2. Disciplinary and Conceptual Limits

In section 1.2, one of the research stages is stated as the investigation of the conceptual basis of "health" as it relates to landscapes. In this regard, it is necessary to define the conceptual parameters of this investigation. This has been done to a large degree by the specification of biophysical landscape health as the principle paradigm for this research. Landscape health in turn stems from ecosystem health, which is a relatively new and emerging field concerned with how to measure and assess biophysical conditions and environmental "distress" (Rapport 1995a & 1995b).

However, biophysical landscape health is essentially about the state and condition of a land area or physical environment called a highly governed landscape (in this particular case). In lay terms, landscape health can also be perceived as being about the "quality of the environment". In this respect, there are a variety of disciplines, fields and conceptual frameworks available to examine an issue as broad as this. The complex and multi-faceted nature of landscape health (e.g. both biophysical and cultural considerations), combined with the variety of conceptual approaches available to examine this issue means it is necessary to have a clear conceptual focus. This section briefly examines a number of possible alternative conceptual approaches before specifying the conceptual and disciplinary focus of this research.

Sustainability is a prominent contemporary paradigm for evaluating human-environment relationships. Sustainability originates from sustainable development, which in turn arose as a result of growing concern from evidence that human populations and their activities are now overwhelming life support systems of the planet. The term was made prominent by the World Commission on Environment and Development (WCED) which defined sustainable development as development that: "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). Sustainability refers to the ability of an activity, economy, or society to sustain itself on a long-term basis (IUCN, UNEP, WWF 1991).

Sustainability is usually cited as the mainstream goal with respect to managing human use of the environmental and ecological resources. It seeks to rectify the current situation caused by the principal model of development in society. This model is represented by an economic system emphasising material consumption and consumerism, which has proven to be incompatible with the maintenance of viable ecological systems. It also recognises how humans and their activities cannot be separated from biophysical systems. This relationship is perhaps even more entrenched in "governed" landscapes as humans have been part of the landscape for so long that what is often considered "natural", has in reality been shaped over time by human influences.[7]

Sustainability could be viewed as an appropriate and acceptable paradigm to examine the health of landscapes. In fact, the concept of sustainability plays an important role in this research, and is reviewed extensively in Chapter 2. The sustainability of specific human activities and resource use is normally considered to be a requirement for healthy biophysical systems. However, sustainability is rejected as the principle paradigm for this study because it is sectoral in nature (as in economic sectors or in relation to human activities), while health paradigms are regarded as considering the functioning of a system as a whole.

Similarly, **agroecosystem health** can be mentioned as another suitable paradigm for examining the state of landscapes dominated by agriculture. Agroecosystem health refers to: "the

[7]This latter point has been especially emphasised in writings by Sprugel (1991), and Nelson & Serafin (1992).

condition, state, or capacity of an agroecosystem" (Smit *et al.* 1998). Agroecosystems are considered to be ecosystems intentionally altered, and often intensively managed, for the purpose of producing food and other agricultural products. Agroecosystem health requires the specification of criteria, and declaration of specific thresholds, by which agroecosystem health can be assessed (Smit *et al.* 1998). While having many advantages, including consideration of human, economic and ecological dimensions, the agroecosystem health paradigm is not considered for this study. It tends to be sectorally oriented (agriculture), while this study is landscape oriented and primarily concerned with the biophysical aspect of landscape health.

Another available methodological approach is **human ecology**. In its broadest context, human ecology is a field of study that is concerned with the interrelationship between humans and their environment. The fundamental premise of human ecology is that humans are an integral part of the environment. With a human ecological approach, the distinction between humans and nature is blurred as humans depend on nature for their existence, and have shaped and manipulated nature to meet their needs (Chorley 1973; Nelson & Serafin 1992). Human ecology can be a useful tool for understanding landscapes in general because many landscape patterns and processes have been created by human settlement and activity patterns over long periods of time. In this respect, it is a potentially useful paradigm for examining landscape health. However, it is most appropriate when a human and cultural focus is desired, which is not the case in this study.

A peripheral technique for assessing health in highly governed landscapes is the process of **risk analysis and assessment**. Risk assessment is a systematic process for describing and quantifying risk associated with hazardous substances, processes, actions, or events. The procedure can be used to examine a variety of hazards where the goal is to estimate the probability of adverse effect on humans, wildlife or ecological systems produced by a specific level of exposure to a chemical or physical agent (Wevers-Carroll & Waltner-Toews 1994). Given the northeastern Italian coastal zone is subject to extremely elevated levels of flood risk (see section

6.3), risk assessment related to flood hazards could be an important component of landscape health. This aspect, however, is excluded from consideration as it introduces another dimension to what is already a difficult undertaking. It also requires additional levels of expertise.

The last conceptual framework to be noted is the discipline of **landscape ecology**. Landscape ecology is a relatively new discipline that emerged from central Europe in the 1950s. In general, it focuses on the quantitative study of ecological patterns and processes over landscapes, or simply the study of the ecology of landscapes (Dramstad *et al.* 1996). It is a more formal systems-oriented holistic science concerned with the functioning of a broader environmental system called a landscape (Zonneveld 1989).

Landscape ecology is closely related to geography in that landscape ecology has often been called a marriage of geography and ecology (biology) (Zonneveld 1989). **Geography** is the larger area of study under which this research falls given the overall geographic perspective and training of the author. However, a geographical approach embodies a number of perspectives (e.g. environmental, human, historical, etc.). The wide-ranging nature of geography thus necessitates the selection of a specific geographic perspective from which research is carried out.

In this regard, this study can be considered as being largely landscape ecological in nature. It not only deals with the land at a landscape level of inquiry, but also borrows many landscape ecological principles and techniques. A more thorough discussion of the discipline takes place in the literature review in section 2.3. Here, the many points of view, perspectives and sub-fields of landscape ecology are outlined. This discussion also examines the landscape ecological perspective adopted by this research.

In preliminary terms, it should be stated that this study is concerned with wider horizontal spatial patterns and processes occurring over landscapes which have implications for landscape health. Landscape spatial patterns and processes provide important indications as to landscape health as there are elements, patterns and processes in cultural landscapes which promote "healthy landscapes". The selection of this perspective is also justified by the fact that it best matches information available for analysis and the technical expertise of the author.

3. Conclusions on Study Boundaries

In summary, it is emphasised that this study is primarily concerned with biophysical aspects of landscape health. With the exception of agriculture, cultural aspects of health are not investigated or analysed to any depth. Some cultural variables are only mentioned as additional indicators of landscape health under certain general characteristics of health listed in Chapter 7.

This study also emphasises "health" as the guiding perspective and paradigm. This means that biophysical landscape health is viewed according to the basic idea of health as a holisitic property concerned with the state and functioning of a biophysical system. This also means that the conceptual review in Chapter 2 will include a thorough review of the idea of ecosystem health and its applications. This study also draws extensively upon the concept of sustainability given that sustainability is closely tied to biophysical health considerations. This concept is also extensively reviewed in Chapter 2.

Lastly, this study is conducted largely from the landscape ecological perspective of geography and borrows heavily from the discipline of landscape ecology. Spatially, the study is conducted at the landscape level, and the overall thrust is biophysical health at this broader level. Methodologically, many parts of the study are landscape ecological in nature and draw upon landscape ecological techniques. The discipline is also concerned with the operation of biophysical systems and thus provides insight into what constitutes healthy landscape systems.

Chapter 2: Literature Review

As mentioned in Chapter 1, the field of **ecosystem health and integrity** and discipline of **landscape ecology** are reviewed for possible contributions to the issue of what constitutes biophysical "health" in landscapes. The existing concept of landscape health is also reviewed although the concept is not well developed and appears to be similar to that of ecosystem health. Also reviewed is the field of **sustainability**, which is related to "health" except that it tends to focus on human use of landscapes and their resources.

The purpose of the literature review is twofold. **One is to review the conceptual basis of key paradigms identified as being useful for assessing landscape conditions and defining biophysical landscape health.** This is an essential aspect of the research because a conceptual base for landscape assessment is needed for the landscape analysis undertaken in Chapter 6. Such a task normally requires the use of existing criteria, frameworks, or scientific fields; especially in the absence of an appropriate conceptual framework for highly governed landscapes. **The second purpose is to examine and identify possible conceptual contributions of these fields for the interpretation of biophysical landscape health for highly governed landscapes.**

2.1 ECOSYSTEM HEALTH AND INTEGRITY

Ecosystem health and integrity is a relatively new and emerging field that in general terms attempts to deal with the issue of land "health". American naturalist Aldo Leopold has been widely credited with the introduction of the concept of land health as a serious scientific project (Callicott 1992). In a series of essays in the 1940's he articulated the concept of land as an organism and suggested that it exhibits properties of health in the same manner as humans and other organisms do. He defined health as: "the capacity for internal self-renewal" and suggested that wilderness could provide the standard or "base datum" with which to evaluate the "performance" of healthy land. Leopold viewed wilderness as the optimal condition of land health primarily because its capacity for self-renewal had not been altered or harmed by humans (Leopold 1989). Leopold's concepts have spawned new theories and approaches to environmental management that are based on the health paradigm, including the emerging field of ecosystem health.

The ecosystem health paradigm can be considered as both a condition and practice. As a condition, a state of health is considered to be a holistic condition of internal order and organisation within ecosystems where the natural or evolutionary processes of self-maintenance and self-regeneration are constantly occurring (Callicott 1992). One comprehensive definition of health is that of an ecological system which is; "stable and sustainable", or is "active, and maintains its organisation and autonomy over time and is resilient to stress" (Costanza 1992a). Similar to the human health metaphor, ecosystem health is taken to mean the absence of ecosystem disease, pathology and malfunction (Rapport 1989a). It is also argued that ecosystems, like other healthy multicellular organisms such as the human body, require the constant turnover of cells to maintain continuity and order in the midst of change (Callicott 1992).

Ecological integrity is closely related to ecosystem health in that health is considered to be a requisite of integrity (Kay 1993). Kay (1991) refers to integrity as the ability of an ecosystem to successfully cope with changes in environmental conditions, or stress, and to continue the ongoing process of its own self-organisation. Self-organisation refers to its evolution and the cycle of birth, growth, death and renewal. In reference to Canadian national parks, Woodley (1993) defines integrity as: "a state of ecosystem development that is optimised for its geographic location including energy input, available water, nutrients and colonisation history.....It implies that ecosystem structures and functions are unimpaired by human-caused stresses and that native species are present at viable population levels".

Ferguson (1994 & 1996) has also proposed a similar version of health for landscapes. Ferguson suggests that landscape health is the state of: "the landscape's taking care of itself". That is, landscape health represents a state of dynamic equilibrium where adjustment and feedback mechanisms are allowed to operate in the self-regulation of the system. Landscape health according to this view is fulfilled in the absence of severe stresses, which act on normal homeostatic[1] mechanisms. In this case, a state of "great health" is marked by the ability to maintain near equilibrium in the midst of frequent minor perturbations (Ferguson 1996).

A more rigorous and practical meaning of health in the ecosystem context is perhaps best summarised by Rapport (1995a). Healthy ecosystems exhibit a number of key properties including: 1) **absence of ecosystem distress syndrome** - a common set of signs present in most heavily damaged ecosystems; 2) **resilience** - in that they recover from normal perturbations and disturbances; 3) **they are self-sustaining** - in that they can be perpetuated without subsidies or depletion of natural capital, or in the case of cultural environments, they do not require increasing subsidy per unit of output; 4) **their functioning does not impair other systems**; and 5) **they are free of environmental risk factors**.

At first glance, the ecosystem health concept is attractive and applicable to the context of cultural and governed landscapes for a number of reasons. One is that what constitutes "nature" in an area does not have to be in a pristine state in order to be judged as healthy since health is based on the ability of ecosystems to regenerate and renew themselves (Rapport 1989a; Callicott 1992). This is important because traditional or commonly held popular and scientific perceptions of pristine "wilderness" environments or climax vegetation states as ideal ecological states are not relevant or applicable to these landscapes. Indeed, what is "natural" in a landscape is often no longer evident because of widespread cultural transformation of landscape elements. Even in the

[1]Homeostasis is defined as maintenance of a steady state in living organisms by the use of feedback control processes (Costanza, 1992a & 1992b).

case of apparently pristine environments, such as tropical rainforests, the actions of aboriginal peoples may have had significant impacts on flora and fauna as in the case of using fire to clear lands for swidden agriculture. In this case, one may also argue that aboriginal peoples may also be part of nature. Therefore an alternative means with which to evaluate these landscapes needs to be adopted.

A reasonably close analogy can be found with human health and ageing. As part of the ageing process, the human body starts to physically deteriorate once an individual passes their twenties. Therefore a comparison of the physical fitness of the average 20-year-old with an average 50-year-old will obviously favour the younger. However, if we do not use age as the basis of comparison, we realise that health is judged on other factors. These can include freedom from disease, injury and impairment (including sufficient capacity to counteract illness and injury); mental, social and emotional well-being; ability to live as a member of a community (Whitbeck 1981); and the ability to realise a person's goals and aspirations given their physical capabilities and repertoire (Whitbeck 1981; Porn 1984).

Second, health is a holistic concept which is generally understood to imply a condition, or state related to the functioning, rather than the physical character and composition, of an ecosystem. This is attractive in the case of most cultural landscapes because the original primeval landscape has been altered significantly, or even entirely eliminated, with the possibility that a number of different equilibriums could have existed during different periods of human history in a region. It is also difficult, if not impossible, to determine when a "wild" landscape became a cultural landscape. Furthermore, if we consider the optimal state as being what existed before widespread human modification, then invariably the cultural landscape represents a decline in "environmental quality". Conversely by the measure of biological function, the landscape may be healthy if human cultures have utilised the land and its resources in a manner which has preserved the integrity of its biological functioning.

Finally, while the concept ultimately reflects value judgements, the general model or metaphor is nonetheless relatively easy to grasp for laymen and decision-makers. As with human health for example, we automatically understand that a state of "poor health", whether perceived by the individual or diagnosed, is an undesirable condition and that "good health" is a positive and socially accepted virtue. Furthermore, the assessment, rehabilitative and prescriptive aspects of ecosystem health are easily related to the care of human health which also encompasses prevention, cure and rehabilitation.

As a field, ecosystem health at its most basic level is concerned with the evaluation or assessment of ecosystem condition. The aim is to determine whether ecosystems are healthy or unhealthy, and what to do if they are unhealthy. Three essential steps for assessing ecosystem health have been identified by Rapport (1995b):

1) Selection of a set of indicators which collectively distinguish well-functioning systems from pathological systems;

2) Development of protocols for diagnosing probable cause of pathology;

3) Development of methods for preventative and rehabilitative actions.

The actual process of evaluating and assessing the health of ecosystems is, however, a complex process. One must first select a **suitable approach** to assessing ecosystem health. This is difficult because there are a variety of different definitions and approaches taken for the monitoring and assessment of ecosystem conditions. The range of possibilities relating to hierarchical scales (individual species, biological communities, ecosystems, landscapes, or the biosphere), spatial scales (local, regional, continental, global), and human values connected with definition and assessment of health further complicates the issue. There have been two notable attempts to make some sense of the wide array of definitions and techniques associated with the concept of ecosystem health.

Costanza (1992a & 1992b) produced a summary of the range of existing definitions or concepts of system health put into practice by individual researchers. These include:

- Health as homeostasis
- Health as absence of disease
- Health as diversity and/or complexity
- Health as stability and/or resilience
- Health as vigour and/or scope for growth
- Health as balance between system components

Homeostasis is defined as the maintenance of a steady state in living organisms by the use of feedback control processes (Pimm 1984). This is considered to be a popular definition of health because any or all system changes represent a decrease in health. If any indicator is seen to change beyond the range of normal variation, the system's health is seen to suffer. However, this simple approach does not consider the constant state of adjustment, change and succession in ecosystems. Changes in ecosystem properties as a result of succession may not necessarily signify a loss in health (Costanza 1992a & 1992b).

Health as absence of disease is a common method of assessing ecosystem health (Rapport 1995b). The operationalisation of this method depends on first defining what is disease in ecosystems. In ecosystems, disease is usually thought of as stresses to the system which result in particular negative effects (Costanza 1992a & 1992b). In an ecosystem context, "stress" refers to an external force, factor, or stimulus that either causes the ecosystem to respond, causes changes in the ecosystem, or results in ecosystem dysfunction (Rapport *et al.* 1985). An ecosystem is also presumed to be healthy if collective signs of distress (derived from "stress"), leading to ecosystem breakdown, are absent. Examples of distress in ecosystems includes reduced biodiversity, loss of nutrient capital, reduction in primary productivity, shifts in biotic composition (resulting in increased dominance of exotics or opportunistic species), reduced size distribution of species, changes in energy flow, and circulation of contaminants in biota and media (Rapport 1995b).

Health as diversity and/or complexity is another possible definition of ecosystem health. Diversity and complexity refer to the number of species in the system, their abundance, and the number of interactions between species (Pimm 1984). These variables are regarded as important indicators\predictors of stability and resilience, which in turn are regarded as important measures of ecosystem health (Costanza 1992a & 1992b).

Stability in the context of ecosystem health refers to the condition where all variables return to the initial equilibrium state following their being perturbed from it (Constanza 1992a & 1992b). **Resilience** refers to the ability of a system to return towards equilibrium, or recover, following a perturbation (Pimm 1984; Forman & Godron 1986; Costanza 1992a & 1992b). These two conditions lead to the definition of health as the ability to recover from stress (Costanza 1992a & 1992b). This has also been referred to as "counteractive capacity". In essence, the healthier the system, the greater its ability to recover from disturbance (Rapport 1995b; Costanza 1992a & 1992b).

A system's **vigour**, or **scope for growth**, is the difference between the energy required for system maintenance and energy available to the system for all purposes. It has been hypothesised that a system's resilience is related to its overall metabolism or energy flow. Both these measures are viewed as possible indicators of health given they attempt to gauge the system's capability to respond to stress in addition to its overall level of activity and organisation. Thus, they are deeper measures of health than stability and resilience alone (Costanza 1992a & 1992b).

Balance is an additional concept of ecosystem health and refers to the idea that a healthy system is one that maintains a proper balance between system components. This concept is drawn from Eastern traditional medicine and is not prescriptive or diagnostic. Instead, it has been used as a general explanation for existing distributions within systems (Costanza 1992a & 1992b).

In summary, these definitions focus on biophysical aspects of systems and Costanza himself notes that while these characteristics represent important criteria of ecosystem health, alone they do not represent comprehensive measures for evaluating the overall health and performance of complex systems. In fact, given the complex nature of such a task, little progress has been made regarding a comprehensive measure of ecosystem health, especially one that encompasses ecological, social and economic variables.

More recently, Rapport (1995b) has explored the range of existing definitions and approaches to assessing ecosystem health and categorises approaches to assessing ecosystem health. Essentially, there are three main approaches used to define, measure and assess ecosystem health:

1) Ecosystem distress syndrome
2) Resilience or counteractive capacity
3) Risk analysis

The first approach assesses health in terms of "ecosystem distress syndrome". This involves the identification of conditions or characteristics which differentiate unhealthy or stressed ecosystems from healthy ecosystems. If an ecosystem does not display signs of distress, it is presumed to be healthy. The second approach emphasises the capability of ecosystems to counteract stress and disturbances. The third approach emphasises the identification of risks or threats to ecosystems and the environment.

The first approach is by far the most common and involves the assessment of ecosystem health based on the presence or absence of conditions that signal ecosystem distress. Notable discussions and applications of this approach include Karr (1981 & 1991), the International Joint Commission (1991), Schaeffer *et al.* (1988), and Canada's first State-of-the-Environment report (Bird & Rapport 1986).

Schaeffer *et al.* (1988) suggest an approach that identifies criteria which provide a functional definition of ecosystem state and condition in terms of health and disease.

More significantly, Karr (1981 & 1991) developed an Index of Biotic Integrity (IBI) using fish communities. This involves monitoring a suite of indicators in a particular stream ecosystem and evaluating ecosystem distress by comparing the conditions of the stream against the standard of conditions found in similar ecosystems where there has been minimal human impact on biophysical conditions. For the evaluation of stream quality, a series of metrics were used including:

- Species richness and composition:
  - Total number of fish species
  - Number and identity of darter species
  - Number and identity of sunfish species
  - Number and identity of sucker species
  - Number and identity of intolerant species
  - Proportion of individuals as green sunfish

- Trophic composition:
  - Proportion of individuals as omnivores
  - Proportion of individuals as insectivorous cyprinids
  - Proportion of individuals as piscivores (top carnivores)

- Fish abundance and composition:
  - Number of individuals in sample
  - Proportion of individuals as hybrids
  - Proportion of individuals with disease, fin damage, and skeletal anomalies.

Each metric is then evaluated using a particular scoring criteria. Ratings of 5, 3 and 1 are assigned to each metric according to whether its value approximates, deviates somewhat from, or deviates strongly from the value expected at a comparable site that is relatively undisturbed. The sum of all 12 metric ratings produces a total IBI score of community quality. Total IBI scores are then compared to integrity classes (excellent, good, fair, poor, very poor, no fish) corresponding to index ranges (e.g. an index score of 12-22 means a community of "very poor" integrity).

Another form of aquatic health index related to ecosystem distress is the Extended Biotic Index (EBI) developed by F.S. Woodwiss in the UK (1964) (Turin *et al.* 1994). This index is a system of biological stream classification based on communities of benthic macroinvertebrates and the effect of pollution on their populations. A modified form of this index was used by Turin *et al.* (1994) for an assessment of surface water quality in Veneto Region rivers. This method was also used to assess stream quality in the Treviso province of northeastern Italy (Loro *et al.* 1994).

In brief, 6 forms of taxa are monitored and numeric values are assigned based on the presence or absence of taxa, and abundance of pollution tolerant species. These data are then transformed to EBI values. Table 2.1 illustrates the conversion of EBI values to water quality classes.

Table 2.1
Conversion of EBI Values to Water Quality Classes

Class	EBI Value	Description
Class I	10-11-12	Unpolluted and unaltered environment
Class II	8-9	Lightly polluted or environment in which some effects of pollution are evident
Class III	6-7	Polluted Environment
Class IV	4-5	Very Polluted Environment
Class V	1-2-3	Heavily Polluted Environment

Source: Turin *et al.* 1994

Another related rating system for aquatic health, that relies on the identification of "distress", was developed by the Water Research Branch of the Italian national research institute *(Istituto Ricerca sulle Acque - Consiglio Nazionale delle Ricerche or **IRSA-CNR**)*(Regione del Veneto 1993). While this method is not specifically called an index, it nonetheless classifies aquatic systems into classes based on the state of their physical and chemical attributes. The rating system comprised four main categories and three sub-categories based on the main ecological functions and human uses of water including:

- maintenance of aquatic life
- potability/domestic use
- irrigation, industrial use
- aquaculture
- aesthetics/recreation
- bathing

The rating system is summarised in Table 2.2 on the next pages. The suitability or compatibility of water for domestic use, aquatic life and bathing was judged according to physical and chemical standards established by European Community directives. Anything other than class **1-2** can be considered as being polluted to some degree. This method was used to assess the water quality of Veneto Region rivers (Regione del Veneto 1993).

The second approach to assessing health relates to the ability of an ecosystem to return to its original condition after disturbances or perturbations. Along these lines, Costanza (1992a) proposes a **Health Index** to assess ecosystem health based on an integration of many of the concepts of health discussed previously (e.g. absence of disease, stability, and resiliency). This index is expressed by the equation:

$$\textbf{HI (Health Index)} = \mathbf{V} \times \mathbf{O} \times \mathbf{R};$$

Where **V** represents **system vigour** - a cardinal measure of system activity, metabolism, or primary productivity; **O** is a system organisation index (between 0 and 1) of the relative degree of system **organisation**, including its diversity and connectivity; and **R** is a system **resilience** index (between 0 and 1) of the relative degree of the system's resilience.

The concept of **ecological integrity**, while somewhat distinct from the concept of health, also tends to approach the assessment of ecosystem condition by emphasising resilience and the ability of the system to cope with stress and perturbations. Key to this ability is the element of **biological** or ecological diversity which is defined as being: "the variety of life forms and its processes" (Noss 1995). An ecosystem with integrity is considered one that is able to maintain its biological diversity (or biodiversity) over time (Noss 1995). Norton (1992) defines managing for

Table 2.2
Water Quality Classifications As Developed by IRSA-CNR

Class	Characteristics	Suitable Uses
1: Very Good Quality *(Qualita ` Buona)*	Watercourses characterised by clean water; almost saturated with dissolved oxygen (concentration ranging from 95-105 percent saturation levels); very low levels of nutrients; only trace levels of N and NH4. This class pertains primarily to springs and the headwaters of rivers that maintain cool temperatures even in summer. Riverbeds are stony and gravely in nature and sediments are mineral in nature. These waters are ideal as spawning areas for fish. Algae, mosses and diatoms are present only in medium densities.	Suitable for domestic use with only primary bacteriological treatment and sand filtration. High aesthetic value and highly conducive to the survival of fish and salmonoid populations. Also suitable for all uses specified in successive classes.
1-2: Good Quality *(Qualita ` Discreta)*	Clean watercourses with high dissolved oxygen content, but only at 85-95 percent saturation levels. NH4 is present in small concentrations. This class pertains to watercourse in their upper reaches. High quality fish species are present with dense populations of algae, mosses and flowering plants.	Suitable for domestic use with physico-chemical (coagulation, sand filtration) and bacteriological treatment. Good quality for bathing with aesthetic/recreational value. Also suitable for all uses specified in successive classes.
2: Fair Quality *(Qualita ` Media)*	Watercourses with medium loads of organic substances and their products of decay. Dissolved oxygen content subject to high fluctuations but still sufficient to permit fish survival. Riverbeds can range from gravels, to sands to muddy sediments. Putrefaction of sediments still largely absent. Watercourses are rich in fish and aquatic life such as molluscs, crayfish, insects and larvae. Dense populations of algae present.	Poor quality for bathing. Suitable for irrigation, aquaculture, and industrial use. Also suitable for all uses specified in successive classes.
2-3: Poor/Mediocre Quality *(Qualita ` Mediocre)*	Watercourses with critical pollution levels. High loads of organic substances create lightly turbid waters. Localised putrefaction in sediments. Dissolved oxygen frequently descends to 50 % levels of saturation. Watercourses are rich in fish and aquatic life although fish species are of low commercial value. Tendency toward massive growth of algae and vegetation carpets.	Suitable for civil use only with maximum physical, chemical and bacteriological treatment. Also suitable for all uses specified in successive classes.

3: Poor or bad Quality *(Qualita` Cattiva)*	Watercourses with heavy pollution loads. Water is made turbid by discharges. Gravely and stony riverbeds are blackened by iron-sulphide. Putrefying sediments accumulate in slow moving sections. Moderate fish populations with periodic die-offs due to oxygen deficiencies. Limited number of larger aquatic fauna species; massive growth of species which thrive in conditions of low oxygen such as sponges and leaches. Presence of micro-organisms and bacteria deriving from sewage discharges. Low growth of algae and aquatic plants.	Waters of poor aesthetic-recreational quality. Conducive only to the growth of only highly tolerant fish and ciprinid species. Also suitable for all uses specified in successive classes.
3-4: Very Poor (bad) Quality *(Qualita` Molto Cattiva)*	Watercourses with very heavy pollution loads. Water is turbid from sewage discharges and riverbeds are covered with putrefying sediments. Periods of total absence of dissolved oxygen. Only sporadic presence of fish. Macrofauna populations consist exclusively of bacteria and micro-organisms. Organic pollution is frequently augmented with toxic substances leading a grave impoverishment of species diversity.	Waters of bad aesthetic quality. Can be used for irrigation of only the most tolerant crop species.
4: Terrible Quality *(Qualita` Pessima)*	Extremely polluted watercourses of very turbid water and muddy riverbeds. In many cases a strong odour of hydrogen sulphate emanates. Dissolved oxygen totally absent or present in very low concentrations. Populated only by bacteria, fungi, and flagellates. Biological deserts exist in conditions of heavy toxic loadings.	Suitable only for the most rudimentary industrial uses.

Source: Regione del Veneto 1993.

ecological integrity as protecting the total native diversity (species, populations, ecosystems) and the ecological patterns and processes which maintain diversity.

Despite the attractiveness of the integrity concept, it is a complicated concept that has proven difficult to measure. Among other things, there is no single or definitive measure(s) of integrity. This is especially true with terrestrial ecosystems compared to aquatic ecosystems where indices of biotic integrity have been used (Noss 1995). Nevertheless, there are objectives with respect to sustaining ecological integrity and suites of indicators have been proposed for its measurement.

Grumbine (1993) lists five specific objectives within the overall goal of sustaining ecological integrity. These include:

1) Maintain viable populations of all native species in situ;

2) Represent, within protected areas, all native ecosystem types across their natural range of variation;

3) Maintain evolutionary and ecological processes (e.g. disturbance regimes, hydrological processes, nutrient cycles, etc.);

4) Manage over periods of time long enough to maintain the evolutionary potential of species and ecosystems;

5) Accommodate human use and occupancy within these constraints.

Potential indicators have been proposed for monitoring ecosystem integrity and biodiversity for a variety of scales (e.g. landscape, ecosystem, species, genetic) (Noss 1990; Woodley *et al.* 1993; Noss 1995). While most examples tend to focus on "natural" systems, Noss (1995) proposes hypothetical indicators of integrity for southern Ontario farmland. This is illustrated in Table 2.3, and provides an example of the application of integrity to cultural landscapes.

Table 2.3
Potential Indications of Integrity, Disintegrity and Recovery in Southern Ontario Farmland

Indications of Integrity	Indications of Threats or Disintegrity	Indications of Recovery
• stable metapopulations of small and medium-sized forest vertebrates and flightless invertebrates (especially of species sensitive to fragmentation)	• high patch extinction rates of small and medium sized forest vertebrates and flightless invertebrates	• increasing populations and patch occupancy rates of small and medium-sized vertebrates and invertebrates sensitive to fragmentation
• low to moderate levels of deer browsing	• high or increasing levels of deer browsing	• declining deer browsing
• low rates of cowbird parasitism	• high or increasing rates of cowbird parasitism	• declining rates of cowbird parasitism
• ratio of exotic:native species biomass in woodlots	• high or increasing ratio of exotic:native species biomass	• declining ratio of exotic:native species biomass
• high connectivity of woodlots (e.g. multiple well-wooded fencerows)	• low connectivity of woodlots	• increasing connectivity of woodlots
• woodlots average >100 ha in size	• small size (<50 ha) of woodlots	• increasing size of woodlots due to forest succession on adjacent agricultural lands
• low forest patch perimeter:area ratios	• high or increasing forest patch perimeter:area ratios	• decreasing forest patch perimeter:area ratios
• high IBI scores (>55 for fish or benthic invertebrates in streams)	• low (<40) or declining IBI scores for fish or invertebrates in streams	• improving IBI scores for streams
• low use of pesticides, fertilisers, and other agricultural chemicals	• high or increasing use of pesticides, fertilisers, or other agricultural chemicals	• declining use of agricultural chemicals

Source: Noss 1995

The risk approach to assessing health focuses on the estimation of potential impacts of known sources of stress on a system (risks) and is best suited for preventative health care as threats to ecosystem health can be identified (Rapport, 1995b). Examples of ecosystem stresses include (Rapport *et al.* 1985):

- Harvesting of renewable resources:
  - -commercial fishing
  - -forest harvesting rates/deforestation

- Pollutant discharges into air, water and land:
  - -PCB's
  - -SO2
  - -pesticides
  - -heavy metals
  - -oil spills
  - -sewage
  - -nutrients
  - -radiation

- Physical restructuring by humans;
  - -purposive land use changes
    - (e.g.land clearing for agriculture, reclamation, urbanisation)
  - -strip mining
  - -shoreworks
  - -pipeline construction

- Introduction of exotics
  - -plants
  - -animals

- natural hazards

Once stresses are identified, risk can be calculated as potential damage to the receiving ecosystem (e.g. loss of productivity, species diversity or other ecosystem services). Simulation models developed on the basis of historical relationships between stress loads and ecosystem response may be used to predict the risks of damage to similar ecosystems by the same class of stress (Rapport 1995b). Schaeffer and Cox (1992) discuss the idea of **ecosystem threshold criteria**, which are conditions that when exceeded increase the risk of the ecological damage and system breakdown. They claim threshold criteria can be based on scientific bases as well as legal, political, social and economic criteria. The knowledge of ecosystem thresholds can provide a practical basis for regulation or mitigation of known stressors.

The distress approach is the most common for a number of reasons. First of all, it is more practical to assess health by of the presence or absence of distress than to assess health through the measurement of system organisation, resilience or counteractive capacity. The latter approach would require methods such as complex simulation modelling and network analysis to predict the dynamics of the system under stress (Costanza 1992a), or the comparison of the recovery rate of stressed systems with those of similar systems under lower levels of stress (Rapport 1995b). The complexity associated with developing such measures is likely one of the reasons there have not been many developments in this area. Furthermore, there is also question as to the usefulness of measures derived from modelling and indices given the limitations associated with endpoint values. With endpoint values for example, one cannot tell why values are high or low, and there is no way to determine the causes of pathology, distress or change in ecosystem properties (Suter 1993).

Moreover, the application of ecological integrity is difficult for a variety of reasons. There is no single definition of integrity; monitoring for integrity is difficult because ecosystems are constantly changing over time due to natural factors and changes are often erratic and unpredictable; and there is no single organisational state corresponding to integrity. Given these difficulties, we may at best only be able to compare areas and conclude with some confidence that one area has more integrity than another (Noss 1995).

Lastly, the risk approach is more suited to preventative health care rather than diagnosis as threshold criteria can be used to regulate human activity in order to protect the environment. Moreover, the development of threshold criteria also requires the development of complex simulation modelling to quantify risk (Rapport 1995b; Schaeffer & Cox 1992).

It is also important to add that certain viewpoints are highly critical of ecosystem health concepts and the application of the "health" paradigm to environmental science. The harshest criticisms appear to come from reductionist perspectives. This vividly illustrates the conflicts between reductionist views and holistic approaches, which embody concepts and approaches such as health. For example, Suter (1993) has called the concept a "bandwagon" and rejects outright the ecosystem health metaphor. He argues that the ecosystem is a poor metaphor for environmental management because ecosystems are not organisms (or super organisms) and thus cannot have properties of organisms such as health. Furthermore, ecosystem health misrepresents medical science because health is not an operational concept for physicians, as they must diagnose and treat specific diseases or injuries rather than calculating indices or degrees of health. Second, operationally defining health requires the creation of indices composed of heterogeneous variables. These indices are highly flawed in his view as;

> *"they have no meaning; they cannot be predicted, so they are not applicable to most regulatory problems; they have no diagnostic power; effects on one component are eclipsed by responses of other components; and the reason for a high or low index value is unknown".*

Wicklum and Davies (1995) also reject the ecosystem health metaphor. Their argument is based on two points. One is that the analogy with human health is invalid because none of the factors that can be used to define an optimum state for humans or "mammalian systems" (e.g. vital signs, homeostatic processes, requisite interconnectedness) are valid for ecosystems. In addition, they argue that it is not possible to define an optimal condition for an ecosystem. Their second point is that the ecosystem health concept is invalid because what constitutes a good or bad ecosystem state is not based on "scientific" principles backed by empirical evidence, but on what is deemed desirable by society.

Rapport (1995b), a proponent of ecosystem health, has conducted a thorough review of challenges and objections to the ecosystem health concept. Objections are based on beliefs that:

1) The health metaphor is inappropriate when applied to the ecosystem level because ecosystems are less homeostatic and less centrally controlled than organisms.

2) There is a lack of objective basis for ecosystem assessment because health is implicitly subjective.

3) Health assessments are impossible because it is not possible to establish norms which differentiate between healthy and pathological ecosystems.

4) The medical model which asserts causality between an agent of disease and illness is too simplistic and limited for applications to ecosystems and environmental science.

While the ecosystem health model has acknowledged shortcomings, Rapport makes some strong counter arguments to these criticisms. One is that ecosystems do in many ways act like organisms in the sense that they have a degree of integration and capacity for buffering external pressures. Stress also acts upon the level of both organisms and ecosystems to degrade systems and make them dysfunctional. Objections regarding the lack of objective basis for ecosystem assessment ignore the fact that there are ecosystem attributes such as biodiversity, productivity and water quality, which can be objectively measured (using assessment endpoints). Changes or declines in these attributes can collectively signify unhealthy ecosystems. Rapport refutes the claim that it is not possible to establish norms of ecosystem health, and cites studies which have evaluated ecosystem condition using "norms" based on historical or "pre-stressed" states. Furthermore, if "norms" or "standards" could not be established for ecosystem function then no ecosystem assessments would be possible. Finally, the medical model has in fact been critiqued by the health sciences and inadequacies pointed out by ecosystem health critics apply equally to medical science.

In summary, the conceptual basis of ecosystem health appears to have a significant degree of relevance to cultural environments, including highly governed landscapes. The idea of "health", as represented by the ability of an ecosystem or landscape to continue the process of its self-renewal, is seen as attractive in environments where the "natural" features have long been eliminated. From a practical standpoint, however, the concept is difficult to put into practice given some of the issues touched upon previously. Thus it has not been operationalised to any great degree. Among other things, assessing ecosystem health or ecosystem integrity requires sophisticated monitoring of ecosystems and human/environment interrelationships to determine such things as the impact of human activities on homeostasis, and the ability to maintain self-organisation. The calculation of such things as ecosystem threshold criteria also requires that we overcome our limited knowledge of ecosystems and the effects of our actions on them. Thus, it remains to be seen whether ecosystem health will move beyond the mostly theoretical stage into common practice.

2.2 SUSTAINABILITY

1. Origins of Concept

The concept and field of sustainability stems from the idea of **sustainable development**. Sustainable development is a wide-ranging term brought into prominence by the release of the report of the World Commission on Environment and Development (WCED 1987). The report was a result of growing concern from evidence that human populations and their activities are now threatening the physical and biological life support systems on which human existence depends. The report advocated the principle of "sustainable development" which was defined in the previous chapter.

Sustainable development can be considered to be a philosophy of living or conducting human affairs that encompasses both ecological and socio-economic considerations. The philosophy seeks to alter the relationship between human activities and the environment in order to combat environmental degradation and fundamental conflicts between ecological integrity and humanity's need and desire for material development and progress. Part of the philosophy is the consideration of how inequities of wealth and resource consumption, both within and between societies, have lead to environmental degradation.

The principle of sustainable development has been widely accepted by world governments. However, its philosophy has not been embraced to the degree necessary to combat ever worsening environmental degradation. This again relates to the conflict between human needs and wants, the pre-eminence of economic concerns, and the preservation of ecological integrity. There is also the widespread view that sustainable development is in the long run a contradiction in terms because of finite limits to not only earth resources, but also on the capacity of the earth's ecosystems to absorb the effects and wastes of human activities. There is also the fundamental philosophical conflict between those who feel that radical transformation of economies and societies is needed to achieve the goals of sustainable development compared to those who feel that the existing system needs modification only. Essentially, not only is this conflict unresolved, but the existing economic system has barely been modified to achieve even a modicum of sustainable development and there appears to be little progress in sight.

Intellectually, the contradictory and ambiguous nature of the term sustainable development resulted in the evolution of thinking to the idea of **sustainability**. Essentially, thinking moved from the initial consensus that the planet is straining from human pressures, and what must be done in general terms, to thinking regarding what must be done to ensure that specific human activities are sustainable over the long term. Sustainability is regarded as a less ambiguous term that more precisely defines the long-term prospects of human activities vis-a-vis the environment. In environmental management circles, it is now usually regarded as the general goal for management of human use of environment and resources with respect to most activities. Quite simply, **a sustainable activity, economy or society is one which can carry on indefinitely or at least on a long term basis** (IUCN, UNEP, WWF 1991).

2. Use of the Concept

The term sustainability has limited use as a general concept. It is usually understood in terms of sectoral human activities, or the state of a particular landscape or ecosystem. As to the former, it can be conceptualised in terms of specific resource sectors or activities. For example, when we speak of sustainable forestry, we refer to a range of practices which make the activity ecologically and economically viable in the long term. In the context of forest resources, sustainability means having a relatively consistent supply of timber available for future generations. Moreover, sustainability also refers to our use of ecological resources (e.g. soil, air, and water) within the context of human settlement and activities (e.g. agriculture, industry). Sustainable use of water resources implies that water-using activities maintain the ability of the supply system to continue to provide this resource. Therefore sustainability can be viewed in terms of both specific resource sectors as well as the impacts of human activities on common property and ecological resources.

Conversely, sustainability also refers to the state of a particular ecosystem or landscape in relation to human use. In the case of agroecosystems, Meyer *et al.* (1992) refer to sustainability of these systems as the capacity to provide food and fibre for basic human needs, and an economically viable living to farmers without jeopardising the structural and functional components of the ecosystem. Altieri (1992) defines sustainability as: "the ability of an agroecosystem to maintain production through time, in the face of long-term ecological constraints and socio-economic pressures". Sustainability also relates to the ability of an agroecosystem to recover after being subjected to stress (Altieri 1992).

Sustainability is closely tied to the idea of ecosystem health and integrity. In the first place, it involves the consideration and implementation of strategies to mitigate human impacts to ensure the continued health and integrity of essential life support systems. At its most basic level, sustainability is also considered an essential condition of ecosystem health. It is also viewed as a comprehensive, dynamic, and multi-scale measure of system resilience, organisation and vigour that is applicable to a range of complex systems including cells, ecosystems, and economic systems (Costanza, 1992a).

3. Potential Contributions to Research

Concerning this research, the principle of sustainability has two potential contributions. Conceptually, the concept of sustainability as an essential **condition** of ecosystem health can be extended to landscapes and landscape health. Ferguson (1994) has done this to some degree as he defines healthy landscapes as those whose capacity for continued self-regulation is "fulfilled" by the absence of severe stresses on feedback and adjustment mechanisms. In these terms, landscape elements such as streams and biotic communities are self-adjusting, where: "each has a healthy home state to which homeostasis tends to return it" (Ferguson 1994). In this sense, healthy landscapes are "sustained" when the long-term self-renewal capacity of biotic communities is not disrupted by human actions.

This premise leads to the second contribution of sustainability as an **indicator** of biophysical landscape health. Human activities conducted in a sustainable manner are those which maintain the integrity of ecological components to ensure that healthy landscapes are maintained. Therefore principles of sustainability are useful not only for evaluating human activities in terms of their overall impact on the state of landscape health, but also for recommending human practices which promote overall landscape health.

4. Agricultural Sustainability

As an indicator of landscape health, it is useful to look at sustainability within the context of the agricultural sector given agriculture is the dominant cultural activity in the landscape under consideration. Sustainable agriculture can be viewed as both a farming system and a holistic philosophy that encompasses the overall performance of the agroecosystem. As to the latter, Troughton (1996)[2] lists 5 objectives of agricultural and rural ecological sustainability:

*1) **Agronomic sustainability** - the ability of the land to maintain productivity of food and fibre output;*

*2) **Micro-economic sustainability** - the ability of farms to remain economically viable and the basis of economic and social reproduction;*

*3) **Social sustainability** - the ability of rural communities to retain their demographic and socio-economic functions on a relatively independent basis;*

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[2]As cited from R. Lowrance (1990) in: *Research Approaches for Ecological Sustainability*, Journal of Soil and Water Conservation, 45(1).

*4) **Macro-economic sustainability** - the ability of national production systems to supply domestic markets and to compete in foreign markets;*

*5) **Ecological sustainability** - the ability of life-support systems, physical and human, to maintain their renewable status and the quality of the environment.*

As a specific farming system, sustainable agriculture emphasises objectives one and five. Sustainable agricultural methods are those which to maintain acceptable levels of agricultural productivity while conserving resources and maintaining ecological sustainability. Barrett *et al.* (1990) define three basic tenets of sustainable agriculture:

1) Reduction in inputs of chemical fertilisers and pesticides;

2) Optimisation of internal ecosystem regulation processes for the retention and recycling of nutrients, creation of favourable microclimates for crop growth, and control of pests;

3) Reduction in the export of soil and nutrients from agroecosystems.

There is, however, no single definition of sustainable agriculture as it can be considered to represent a range of practices which are designed to achieve these goals to varying degrees according to local climatic and soil conditions. Hence, a wide variety of farming systems has been developed to meet these goals. Hill and MacRae (1992) list a number of agricultural forms according to a spectrum that classifies them from low sustainability to high sustainability. In order of increasing sustainability, some examples include: conventional agriculture (high input crop monocultures), low input sustainable agriculture, organic agriculture, biological agriculture, ecological agriculture, permaculture and natural agriculture.

5. Sustainable Agriculture in the Veneto Context

Given the wide array of farming systems whose goal is "sustainability", it is perhaps appropriate to focus on the bureaucratic view of sustainable agriculture within the northeastern Italian context. This is outlined by the Veneto Region's Agricultural Development Office *(Ente Sviluppo Agricolo Veneto or ESAV)* (ESAV 1995). ESAV defines both the ecological and socio-economic components of sustainable agriculture. In general, sustainable agriculture is defined as: "an integrated system which consents to join productivity and profitability with the needs of environmental management". In socio-economic terms, sustainable agriculture requires the use of "techniques compatible with environmental management[3]", while ensuring:

- *overall profitability comparable to existing forms of agriculture[4];*
- *relatively consistent agricultural production of high (and healthy) quality and relatively stable prices;*
- *maintenance of production of valuable non-food crops.*

Conversely, it should avoid:

- *excessive production (with respect to market needs) arising from technologies and methods incompatible with "environmental management";*
- *practices which guarantee high qualitative standards and/or absolute respect for the environment at the expense of reduced production.[5]*

ESAV goes on to state that sustainable agriculture is based on effective management of both natural resources vital to agriculture (soil, water, nutrients, energy) and natural adversaries to agriculture (parasites, insects and weeds) and requires practices which:

- *conserve soil quantity, structure, fertility and organic matter;*
- *ensure efficient nutrition of plants;*
- *preserve water quality;*
- *reduce production costs (consumption of energy, water, fertilisers, pesticides and herbicides).*

Notable is the emphasis on both socio-economic and ecological considerations. Specific techniques of sustainable agriculture include:

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[3]In this context "environmental management" should be understood to mean management practices compatible with conservation of agricultural resources and their ecological base.

[4]A study commissioned by ESAV for a specific farm employing methods of biological agriculture revealed that input costs for corn and soybean crops were somewhat lower than conventional agriculture, while production was more or less equal (Bustaffa & Soldati 1995).

[5]This statement appears to contradict true sustainability, but is probably no more contradictory than the conventional convictions behind the idea of **sustainable development**, which implies that the adoption of sustainable practices is not expected to lead to a reduction in economic activity.

- *crop rotation and mixed cropping to reduce the need for chemical fertilisers and assist with natural biological control of insect pests, parasites and weeds;*
- *reduced or minimum tillage to conserve energy and maintain soil structure;*
- *use of forage crops and crop residuals to maintain organic content of soils (by plowing back into soil);*
- *use of mineral fertilisers to compensate for elimination of chemical fertilisers;*
- *use of selected seeds engineered for productivity, resistance to climatic adversity, and resistance to disease and insects;*
- *adopting of integrated pest/disease control through a combination of resistant seeds, mixed cropping and rotation, selective use of pesticides, and appropriate cultivation techniques.*

Additionally, a more rigorous form of sustainable agriculture exists in the form of "biological" agriculture. This is a regulated practice in the European Union, and is practised in certain farms in northeastern Veneto. In this context, biological agriculture refers to agriculture which does not utilise synthetic chemical inputs (chemical fertilisers, pesticides, herbicides). Instead it uses techniques which take advantage of the vital cycles of plants and micro-organisms as substitutes (Carrer 1993; Bustaffa & Soldati 1995).

Within a modern context, this form of agriculture represents perhaps the best indication of a sustainable farming system. It is the most ecologically compatible form of agriculture in that it has eliminated chemical inputs. From a nutrient and fertility conservation standpoint, biological agriculture has also demonstrated its technical feasibility. It has also proven to be competitive with conventional "high input" agriculture from a cost perspective (Bustaffa & Soldati 1995).[6]

The broad objectives of biological agriculture are similar to sustainable agriculture and include:

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[6]Whether this definition of biological agriculture approximates the common definition of "***organic***" agriculture is unclear given how Hill and MacRae (1992) define organic farming in general terms as: "a range of approaches within the broader sustainable agriculture spectrum". Furthermore, Madeley (1996) defines organic farming as that: "characterised by a lower intensity of reliance on synthetic and other external inputs, a higher biological intensity of production which enhances the long-term fertility of the soil, use of natural methods for weed, disease and pest control, and an extensive livestock management that pays due regard to animal needs". Conversely, Hill and MacRae do identify specific practices associated with organic agriculture, such as reliance on crop rotation, mechanical cultivation, and biological insect and pest controls, which are similar to those identified by Bustaffa & Soldati (1995) for biological agriculture.

- *the maintenance and rehabilitation of soil fertility;*
- *the minimisation of environmental impact and avoidance of pollution related to agricultural activity;*
- *better and more efficient use of existing agricultural resources (soil, climate, genetic diversity) and natural biological systems;*
- *realisation of more self-sufficient agriculture through the reduction of external inputs;*
- *improvement of nutritional and aesthetic aspects of agricultural products;*
- *maintenance of floral and faunal biological diversity in agroecosystems;*
- *maintaining adequate levels of farm income and productivity (Bustaffa & Soldati 1995; Carrer 1993).*

A true biological system operates on what is called a "closed cycle" where plant fertilising nutrients are installed and recycled within the operation of the farm through forage crops and manure. The only occasional exception to this is the use of organic or mineral-based **P** and **K** fertilisers. Furthermore, both integrated and biological[7] means can be used to combat parasites and insect pests. To achieve a closed system without chemical inputs, the farm adopts a number of specific techniques, including:

- *crop rotation[8] and mixed cropping to maintain soil fertility, to help combat weed growth, and to help combat insect and parasite infestation;*
- *disking of forage crops into the soil to restore nutrient and organic content of soil;*
- *minimum or no tillage to conserve soil structure, soil moisture and reduce energy consumption;*
- *use of integrated methods of weed control such as mechanical weeding with specially designed implements and use of "false seeding" (la falsa semina)[9];*
- *replanting of hedgerows along collector ditches to assist with natural biological control of insect pests and parasites;*
- *use of subterranean tubular drainage to facilitate minimum tillage through efficient movement of farm machinery (Carrer 1993; Bustaffa & Soldati 1995).*

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[7]Biological control refers to a range of methods used to control pests such as the use of predatory insects and organisms, or more resistant genetically engineered plants. Integrated control refers to the use of interacting measures such as more resistant plants, cropping patterns and seeding density (e.g.wider spacing between rows of crops) (Carrer 1993).

[8]A typical crop rotation as practiced in a Province of Venezia biological farm consists of a five year cycle of: 1) row crops (corn, sunflowers, sugar beet); 2) cereal crops (wheat, barley, rye); 3) leguminous crops (soybeans); 4) cereal crops; and 5) forage crop set aside (Bustaffa & Soldati 1995).

[9]This is a practice conducted prior to crop seeding where the seed bed is first prepared to allow infestants to germinate. They are then removed by passing with a harrow.

In summary, while the production and environmental goals of each form of sustainable agriculture are similar, there are some important differences between the two forms examined. The main difference lies in the objectives of agriculture. The main objective of biological agriculture is to operate within a "closed" system to completely eliminate chemical inputs. In contrast, the system defined by ESAV implies a more efficient form of agriculture, but not a closed system. Efficiency results from reduced chemical inputs, which reduces costs and environmental impacts. The techniques of both forms of agriculture are summarised in Table 2.4

The methods of biological agriculture are cited from Bustaffa and Soldati (1995), and refer to those practised on a biological farm, emphasising row and root crops, and located on reclaimed territory within the northeastern Italian province of Venezia. Notable is the omission of the use of animal manure for fertilisation, as mixed farming and the use of animal fertiliser is usually indicated as a vital component of sustainable agriculture (Altieri 1992). This reflects the emphasis on cash crops in these highly governed agricultural landscapes. As footnoted earlier, the profitability of their biological farm is comparable to a farm using conventional methods.

Table 2.4
Methods of Sustainable and Biological Farming - Veneto Region

Sustainable Agriculture	Biological Agriculture
• crop rotation/mixed cropping • reduced/minimum tillage • plowing of forage crops/crop residuals into soil for soil organic content • use of mineral fertilisers (P and K) to reduce use of chemical fertilisers • integrated pest and disease control (through resistant seeds, crop rotation, strip cropping)	• crop rotation/mixed cropping • minimum/no tillage • plowing of forage crops/crop residuals into soil for soil organic content • use of organic fertilisers (e.g. guano) and leguminous crops for fertilisation • integrated and natural biological control of pests and disease (through hedgerows and use of beneficial predatory insects) • integrated weed control using indirect (crop rotation, cover crops)and direct (false seeding, mechanical weeding) methods • use of subterranean tubular drainage

Sources: ESAV 1995; Bustaffa & Soldati 1995.

6. Sustainable Farming Systems and Biological Diversity

Another perspective from which to assess the sustainability of agriculture and farming systems is through biological diversity, which is seen as an important component of ecological integrity. The maintenance of biological diversity is usually considered one of the objectives of sustainable agriculture especially in light of the beneficial role predatory insects play as a substitute for agricultural chemicals. Table 2.5 lists characteristics of agroecosystems, and agricultural techniques which promote biodiversity. Many of these could also be used for the assessment of agriculture and its overall sustainability.

Table 2.5
Beneficial Practices for Conserving and Improving Biodiversity in Agroecosystems

Practices Beneficial to Biodiversity:	Practices Detrimental to Biodiversity:
• hedgerows	• wild vegetation removal
• dikes with wild herbage	• tubular drainage or vegetation removal
• polyculture	• monoculture
• agroforestry	• monosuccession
• rotation with legumes	• bare soil
• dead and living mulch	• conventional cropping
• strip or ribbon cropping	• conventional plowing
• alley cropping	• simplified landscape and woodland clearing
• minimum tillage, no tillage, ridge tillage	• intensive input farming
• mosaic landscape and porosity	• chemical fertiliser
• organic sustainable farming	• conventional chemical pest control
• organic fertiliser	
• biological pest control	

Source: Paoletti 1993b & 1995.

7. Components of Sustainable Agricultural Landscape Systems

In conclusion, defining sustainability beyond general definitions is difficult because of the concept's range of applicability. This is the case even when concentrating on sectoral activities such as agriculture. As indicated, there are many different forms of "sustainable" agriculture. Sustainability itself is not a precise measure. One has to define sustainability given there are different degrees of sustainability. This is clearly illustrated by the often-subtle differences between biological and sustainable agriculture in the Italian context (Table 2.4).

However, it is still possible to define sustainable agricultural systems, or criteria which collectively distinguish sustainable agricultural systems from unsustainable ones. In this regard, the preceding review provides many indications as to what constitutes sustainable agricultural systems in highly governed landscapes. A summary of some considerations for assessing the sustainability of agricultural systems is listed on Table 2.6 on the next page. They may also be referred to as considerations for agroecosystem health. Under each is included some specific criteria which collectively can be used to determine whether or not agriculture is sustainable and conducive to biological diversity. Some social and economic considerations are also included for discussion purposes. This framework is later utilised in Chapter 6 for the assessment of Lower Piave agriculture.

Table 2.6
Considerations for Assessing Agricultural Sustainability/Agroecosystem Health

• **Economic Considerations:** 1) long term macroeconomic viability of agricultural sector; -yes?, no?; existing trends? 2) microeconomic viability of individual farms; -yes?, no?; existing trends?
• **Social Considerations:** 1) long term viability/health of farming communities; -population/migration trends -employment opportunities -economic health of communities
• **Landscape/Ecological Considerations:** 1) presence of "natural" vegetation; -hedgerows -terrestrial natural areas -wild vegetation along unfarmed areas; 2) overall level of diversity (heterogeneity) in landscape; -land use diversity -crop diversity 3) distress and risk factors in landscape from agriculture; -risk factors present (e.g. agricultural inputs; animal waste discharges) -distress factor present (e.g. water quality problems) -levels of distress
• **Farming System Considerations/Characteristics:** 1) characteristics of farming systems; -conventional crop monocultures? -mixed farming? -polycultures/multiple cropping? 2) farming methods; -conforming primarily to conventional high input agricultural methods? -conforming to biological farming methods? -number of farms employing "biological" or "alternative" farming methods

2.3 LANDSCAPE ECOLOGY

German geographer and ecologist Carl Troll introduced the concept of landscape ecology in the late 1930's. Landscape ecology has been described as a marriage of geography (land and landscape) and biology (ecology), where the "horizontal" or spatial approach of the geographer is combined with the "vertical" approach of the ecologist (Vink 1983; Naveh & Lieberman 1984; Zonneveld 1989). Since its introduction by Troll, it has emerged as a scientific discipline concerned with the study of ecological patterns and processes over a defined area or *landscape*. It is also concerned with the relationships between individual and of groups of organisms on a given land surface (Vink 1983; Zonneveld 1989). Within a European context, landscape ecology is presently viewed as a scientific basis for land use and landscape planning, land evaluation and classification, impact studies, landscape design, and conservation (Vink 1983; Naveh & Lieberman 1984; Zonneveld 1989).

Landscape ecology is considered to be a "trans-disciplinary" science because it not only combines the methods of various sciences, but also integrates other disciplines in its basic philosophies (Naveh & Lieberman 1984; Zonneveld 1989). Landscape ecological studies touch the realm of geographers, ecologists, biologists, soil scientists, vegetation scientists, foresters, agronomists, conservationists, land use planners, resource managers, system scientists, and in recent years remote sensing specialists (Vink 1983; Naveh & Lieberman 1984; Zonneveld 1989). The wide-ranging disciplinary realm of the science, combined with its many applications, means that landscapes can be observed from a variety of perspectives, and studied from both ecological and spatial angles.

An effective attempt at simplifying the broad range of landscape ecology is provided by Zonneveld (1989). He has identified three "points of view" from which landscape ecologists are concerned about landscapes. These interrelated points of view are identified as the visual or **aesthetic** aspects of landscape (e.g. scenery), the **chorological** aspect of landscape, and the view of **landscape as ecosystem**. The visual or aesthetic aspect of the land conforms to the oldest meaning of the world landscape. The landscape paintings dating from the 16th century masters until today is an expression of this kind of approach (Vink 1983). The chorological aspect of landscape is concerned with horizontal patterns on the landscape. This includes the spatial interplay of natural phenomena such as the pattern of individual surface patches belonging to different land attributes in landscapes (e.g. rocks, landforms, soils, vegetation patches). In landscape terms, patches are defined as nonlinear surface areas differing in appearance from their surroundings (Forman & Godron 1986).

The last view is the most comprehensive, and incorporates the two preceding views. This view sees the landscape as an open system, where physical, biological, and noospherical forces interact with each other on the earth's surface. The noosphere refers to the sphere in which human knowledge is active (Vink 1983). The interaction of these forces forms complex three-dimensional phenomena that are recognised in terms of both horizontal patterns of mutually related elements (landscape units), and vertical strata of land attributes (e.g. air, vegetation, soil, bedrock).

A study by Bas *et al.* (1990) provides an illustration of the view of landscape as ecosystem which combines both horizontal and vertical perspectives. Their study examined the historical geographical development of a lowland brook valley in the Netherlands with an emphasis on the historical interactions of humans and land use with ground water hydrology. Historical land use changes were detailed using topographic maps. The effects of historical land use development on hydrology at different points in history was examined using ground water records, and then illustrated using a vertical cross sectional scheme. In this study, the authors demonstrated how horizontal landscape development affected ecological processes related to groundwater at a given location.

The preceding "points of view" identify the two principal perspectives or dimensions of landscape ecological study. The horizontal dimension is also known as the **chorological** approach, and is primarily concerned with the distribution of, and relationship between, holistic "landscape units" in space[10]. Landscape units comprise a hierarchy ranging in scale from:

- The **ecotope** (or site) – the smallest holistic land unit characterised by homogeneity of at least one land attribute of the geosphere (e.g. atmosphere, vegetation, soil, rock, water), and with nonexcessive variation in other attributes;
- The **land facet** (microchore)– a combination of ecotopes, forming a pattern of spatial relationships, and being strongly related to the properties of at least one land attribute (mainly landform type);
- The **land system** (mesochore)– a combination of land facets that form one mapping unit on a reconnaissance scale;
- The **main landscape** (macrochore)– a combination of land systems in one geographical region.

Under this view, landscape ecology is primarily concerned with: 1) spatially heterogeneous areas; 2) fluxes and redistribution of materials and energy among landscape elements; and 3) human influences on, and their reciprocal responses to, ecological processes (Risser 1987). Heterogeneity is one of the fundamental concepts and focal points of landscape ecology, and refers to the diversity of spatial and temporal attributes of landscapes (Risser 1987). It also has implications for landscape health and integrity, which is discussed later in this section.

The vertical dimension is also known as the **topologic** dimension. This perspective emphasises the study of the functional interplay between "vertical" biophysical land attributes in a given site or ecotope (Naveh & Lieberman 1984; Zonneveld 1989). Vertical biophysical land attributes include strata ranging from the sun's energy, atmosphere, climate, vegetation, fauna (including humans), hydrology, landforms, soil and bedrock. This perspective is differentiated from purely ecological study in that biology is not the dominant discipline, but of equal

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[10]The landscape unit concept was first proposed by I.S. Zonneveld (1972), and is cited here from Naveh and Lieberman (1984).

importance with other disciplines. While focused at the lowest possible scale (ecotope), topological relationships and their study is the basis for understanding more wider scale chorological relationships (Zonneveld 1989).

In addition to the points of view and dimensions of landscape ecology just mentioned, there are specific sub-fields of landscape ecology. Zonneveld (1989) has identified five distinct sub-fields:

- Morphology
- Classification
- Chorology
- Chronology
- Relationships

Morphology is the description of landscape structure and its elements. This can be concerned with either vertical land attributes within a particular biotope, or horizontal attributes (e.g. vegetation patches, mosaics, and land units). Landscape classification normally consists of the ordering and description of land attributes using an abstract typology such as a legend map. Examples of land classification include soil surveys and vegetation classifications. As described earlier, chorology is the study of horizontal spatial patterns and variations. Chronology is the study of the temporal variation of both land units and land attributes.

The last sub-field is the study of the relationships between all land attributes. This is landscape ecology in the narrow sense, as its main task is to gain knowledge about the relationships among the building blocks of the landscape in order to understand the functioning of a landscape as a system. This is, however, related to the first four descriptive sub-fields as in order to understand relationships in a landscape, it is necessary to order the elements and structure of the system (Zonneveld 1989).

As stated in Chapter 1, this study borrows heavily from conceptual and methodological aspects of landscape ecology. Concerning point of view and perspective, **this study is primarily concerned with horizontal spatial structure and change at a broader landscape level,**

including their relationship to "health" principles. Chapter 5 is especially concerned with temporal change in spatial landscape structure, and what this tells us about landscape conditions in relation to "health" principles discussed in this chapter. This focus is attributable to both the geographic perspective and training of the author, as well as study design, and the nature of information gathered for analysis (see Chapter 4).

Conceptually, landscape ecologists such as Forman and Godron (1986) perhaps best represent the horizontal chorological landscape ecological perspective. According to this school, there are three fundamental characteristics which not only define landscapes, but provide the focus of landscape ecological study. These include:

1) **Structure** - the spatial relationships among the distinctive ecosystems or "elements" present. Or more specifically, the distribution of energy, materials, and species in relation to the sizes, shapes, numbers, kinds, and configurations of ecosystems.

2) **Function** - the interactions among spatial elements. That is, flows of energy, materials, and species among the component ecosystems.

3) **Change** - the alteration in the structure and function of the ecological mosaic over time (Forman & Godron 1986).

According to the horizontal spatial perspective, the building blocks of landscapes are patches of ecosystem (Risser 1987). These normally represent areas of vegetation and animal communities, and may be embedded in a matrix (Forman & Godron 1986).

From a methodological standpoint, the chorological perspective of landscape ecology is adopted in Chapter 5 when landscape transformation and associated landscape structural changes are qualitatively and quantitatively examined. Methodologically, this procedure is described in Chapter 4, and is based on the availability of landscape level reconnaissance information (topographic maps), powerful computers, and mapping and GIS (geographic information system) software. Landscape structural characteristics are later tied to landscape health based on established research on landscape relationships. Some of the most important relationships are cited in this section, but are also referred to at appropriate points throughout the analysis in Chapter 6.

This chorological focus is based not only be the needs of this study, but also on the increasing quantification of landscape structural aspects using simple measurement and statistical analysis. Using land cover data digitised within a GIS, common landscape spatial indicators of structure, such as number, cover, size and shape of landscape patches, perimeter/area ratio, hedgerow length and connectivity, can be calculated using relatively simple statistical analysis. These can then be correlated with ecological processes and temporal change (Simpson *et al.* 1994).

This approach has been taken a step further with the development of indices to measure significant landscape patterns (heterogeneity) and to discriminate among major landscape types. Four important indices are those that measure **Diversity**, **Dominance**, **Contagion** and **Fractal Dimension**. These measures have been successfully applied at U.S. regional landscape levels using remotely sensed data (Turner & Ruscher 1988; O'Niell *et al.* 1988). These are now discussed as a prelude to the application of some of these measures in Chapter 5.

Diversity is a measure of the heterogeneity of the landscape and is measured by the formula:

$$H = -\sum_{k=1}^{m} (P_k) \log(P_k)$$

where P_k is the proportion of the landscape in cover type **k**; and **m** is the number of land cover types observed. The larger the value of **H**, the more diverse the landscape.

The **Dominance** index measures the extent to which one or a few land uses dominate the landscape (O'Neill *et al.* 1988). It is measured by the formula:

$$D = H_{max} + \sum_{k=1}^{m} (P_k) \log(P_k)$$

where **Pk** is the proportion of the landscape in land use **k**; **m** is the number of land use types observed on the map; and **Hmax = log(m)** - the maximum diversity when all land uses are present in equal proportions. Inclusion of Hmax in this equation normalises the index for differences in numbers of land uses between landscapes. As the summation of terms in the Diversity equation is negative, the dominance index expresses the deviation from the maximum. Large values of **D** indicate a landscape that is dominated by one, or few land uses, and is associated with either intensive crop production or undisturbed forests. Low values indicate a landscape that has many land uses represented in approximately equal properties (O'Neill *et al.* 1988; Turner & Ruscher 1988).

The **Contagion** index measures the "adjacency" of land cover types, or the extent to which land uses are aggregated or clumped. This index is calculated from an adjacency matrix, **Q**, in which **Qij** is the proportion of cells of type **i** that are adjacent to cells of type **j**, such that:

$$C = K_{max} \div \sum_{i=1}^{m} \sum_{j=1}^{m} (Q_{ij}) \log(Q_{ij})$$

where **kmax** = 2m log(m) and is the absolute value of the summation of (Qij) log(Qij) when all possible adjacencies between land cover types occur with equal probabilities. At high values of C, large contiguous patches, or a clumped pattern of land cover type is found on the landscape. At low values, the landscape is dissected into many small patches.

The Fractal Dimension is an index of the complexity of shapes on the landscape. It is estimated by regressing polygon area against perimeter for each patch on a digitised map. The Fractal Dimension is expressed by the relationship:

$$D = 2\,S$$

where **S** is the slope of the regression. If the landscape is composed of simple geometric shapes likes squares and rectangles, the fractal dimension will be small (around 1.0). If the landscape contains many patches with complex and convoluted shapes, the fractal dimension will be large.

These indices provide specific measures that require interpretation based on peculiar land cover characteristics, temporal change and human processes at work in the landscape. However, the successful application of these indices from a technical standpoint demonstrates how landscape structural patterns can be calculated at the broader regional landscape level. The analysis of landscape structure using these techniques is significant from the standpoint that landscape structure and heterogeneity appear to hold important keys to landscape health.

Specifically, certain landscape structural features tend to promote landscape health and integrity compared to others. For example, the existence of hedgerows and *terrestrial natural areas* within agricultural landscapes, such as forests, woodlots, wetlands, old fields undergoing succession, and grasslands, perform a variety of beneficial ecological and socio-economic functions. From an ecological perspective, these elements help to regulate biophysical processes (e.g. water and nutrient cycling) and provide habitat and life support systems for a variety of organisms. They also provide beneficial natural resources such as fish, game, edible wild plants, timber and fuelwood, as well as providing aesthetic benefits (Zanetti 1988; Vianello & Vita, 1994; Couturier & Smit 1994).

Furthermore, soil biological activity and biodiversity are linked with the shape and structure of landscape. Hedgerows, undisturbed field borders, cover crops and living mulches are generally favourable to both increased diversity and biomass of soil macrofauna and invertebrates, compared to simplified landscapes with none of these elements (Paoletti *et al.* 1992; Paoletti 1993a; Paoletti 1995; Paoletti & Bressan 1996). Landscape structural aspects also have an important impact on water fluxes in the landscape. For example, the existence of hedgerow networks in agricultural landscapes help to regulate runoff and water flow with positive effects of reduced soil erosion, nutrient run-off and stream flooding (Forman & Godron 1986; Burel & Baudry 1990; Burel *et al.* 1993). The positive ecological benefits of hedgerows are ultimately related to landscape health and are discussed in more detail in section 6.5 when vegetation changes are examined.

In the discussion of ecological integrity in section 2.1, it was mentioned how biodiversity is a crucial component of ecological integrity as diverse landscapes are better able to cope with stress. In this respect, it is generally accepted that landscape structural variables such as patch size, heterogeneity (overall diversity of land cover types) and connectivity exert a huge influence on biodiversity (Noss 1990; Meyer *et al.* 1992; Kalkhoven 1993; Paoletti 1993a, 1993b & 1995). Hedgerow corridors and associated connections (connectivity) play a particularly important role in the transfer and migration of genes among species (Forman & Godron 1986). A summary of landscape structure and composition indicators associated with monitoring for biodiversity and ecology in agroecosystems is listed in Table 2.7.

In short, a fragmented heterogeneous agricultural landscape with a high degree of connectivity is considerably more amenable to the maintenance of biodiversity, and ecological integrity, than a simplified homogeneous landscape. In agricultural landscapes, it has been frequently stated that diversity at all hierarchical levels should be the goal of future agricultural development. This ensures genetic diversity, which promotes greater adaptability under changing ecological conditions (Paoletti *et al.* 1992; Medley *et al.* 1995).

Table 2.7
Landscape Structure and Composition Indicators in Agroecosystems

Noss (1990)	Couturier & Smit (1994)
• heterogeneity • connectivity • spatial linkage • patchiness • porosity • contrast • grain size • fragmentation • configuration • juxtaposition • patch size frequency distribution • perimeter area ratio • pattern of habitat layer distribution	• total natural area • number of contiguous tracts • average contiguous tract size • relative connectivity • relative tract connectivity • total hedgerow length • relative hedgerow length • relative hedgerow connectivity

Paoletti (1993b & 1995)	Meyer *et al.* (1992)
• hedgerows • dikes with wild herbage • polycultures • mosaic landscape structure porosity	• overall land use and land cover data • landscape elements: -woodlots -shelterbelts -hedgerows • heterogeneity (overall diversity) • abundance and size of patches • shape of patches • fragmentation • broad scale measure of pattern • vertical structure of habitat

2.4 CONCLUSIONS

In summary, the three fields reviewed provide differing perspectives regarding the broad issue of biophysical "health". Each perspective makes substantial contributions towards both assessing the condition of highly governed landscapes in Chapter 6, and formulating an interpretation of landscape health in Chapter 7. Ecosystem health and integrity are most useful in the way they look at land as an organism or living system, and through the corresponding identification of properties which signify "health" (e.g. resilience, stability, balance, diversity, self-organisation, and freedom from disease, pathology and environmental risk factors).

Sustainability is useful as an indicator of landscape health. It is, as a means through which sectoral activities can be assessed as to whether they can continue in the long term without damaging both the biophysical resource base, and the overall health and integrity of landscapes.

The contribution of landscape ecology to landscape health lies in two areas. In methodological terms, the school of landscape ecology concerned with horizontal spatial structure provides the model for the analysis of landscape patterns and change in Chapter 5. This is then related to landscape health based on both horizontal and vertical landscape ecological relationships demonstrated to be amenable to landscape health. Some fundamental relationships between overall landscape structure and biophysical "health" have been introduced in the previous section. Further discussion and reference to these relationships also occurs at appropriate points in Chapter 6 when the state and condition of key landscape elements in the Lower Piave is assessed.

Chapter 3:
The Venetian Plain and Lower Piave Area

3.1 INTRODUCTION

This chapter introduces the Lower Piave study area and examines the historical and cultural context of landscape governance in the Lower Piave and surrounding Venetian Plain. Section 3.2 first introduces the general characteristics of the Lower Piave study area which is the highly governed landscape under investigation in this research. Section 3.3 provides a landscape history of the Venetian Plain and Lower Piave area prior to the 20th century. The landscape history provides important geographical and historical background information on landscape evolution and the historical and cultural context of landscape governance in the Venetian Plain. It also provides important information as to the biophysical nature of traditional Venetian landscapes.

This background information is important for a number of reasons. One reason is that 20th century events detailed in Chapter 5 are related to historical and cultural patterns of land governance in the Venetian Plain. In other words, 20th century reclamation of the Lower Piave to a highly governed landscape occurred within a larger cultural and geographical context. In order to view 20th century landscape transformation within its proper cultural and landscape context, it is necessary to understand regional historical and cultural patterns of land governance.

The second reason is that cultural norms of historical landscape governance, and the character of past landscapes, also provide important indications as to biophysical landscape health. In this chapter it is demonstrated how landscapes and their governance was usually designed to maintain a landscape that provided the medium and resources for human subsistence. In this case, the land provided both the medium for successful cultivation, and necessary natural resources such as game, wood and fuel. As a consequence, the characteristics of these landscapes conformed to many of the ecological conditions and principles discussed in the literature review concerning "healthy" landscapes. Thus, traditional landscapes provide important indications as to historical characteristics of landscape health. These characteristics also provide an important comparison with contemporary modern landscapes.

For the purposes of this chapter, a landscape historical approach is utilised to examine the evolution of landscapes and their characteristics during different eras. It should be noted that the state of landscapes in relation to landscape health principles is largely deduced through a combination of historical landscape patterns and governance, human motivations behind these historical patterns, and landscape characteristics usually associated with "health" (as discussed in Chapter 2). A deductive process is used because landscape health as perceived in this research does not exist in Italian landscape literature, and one will not find discussion on the relationship between traditional landscape states and "health.

The landscape history is organised according to prominent historical eras. The time periods or historical eras have been adopted from a study of Venetian landscapes by the *Provincia di Venezia* (Provincia di Venezia 1994a). These include:

- pre Roman/antiquity
- Roman
- Medieval
- Venetian/Renaissance
- Austrian and post unification (1861)

The landscape history conforms to a simple historical geographical approach utilising existing literature and historical maps to chronicle landscape evolution. Simple description accompanied by maps is the principal tool used to illustrate the evolution of landscapes.

The 20th century is omitted as an entire chapter is devoted to this (Chapter 5). At that time the transformation of the Lower Piave to a highly governed landscape is illustrated and discussed in detail. This era is considered in more detail because the highly governed landscapes created through reclamation are the basis for the analysis of Chapter 6, and the conceptualisation of health. At the conclusion of Chapter 5 is also found a summary of findings regarding historical landscape change and transformation, human landscape governance, and cultural perceptions of landscape governance in this region. These conclusions combine historical insights from both Chapters 3 and 5. They form part of the overall biophysical landscape health puzzle and are applied in Chapter 7.

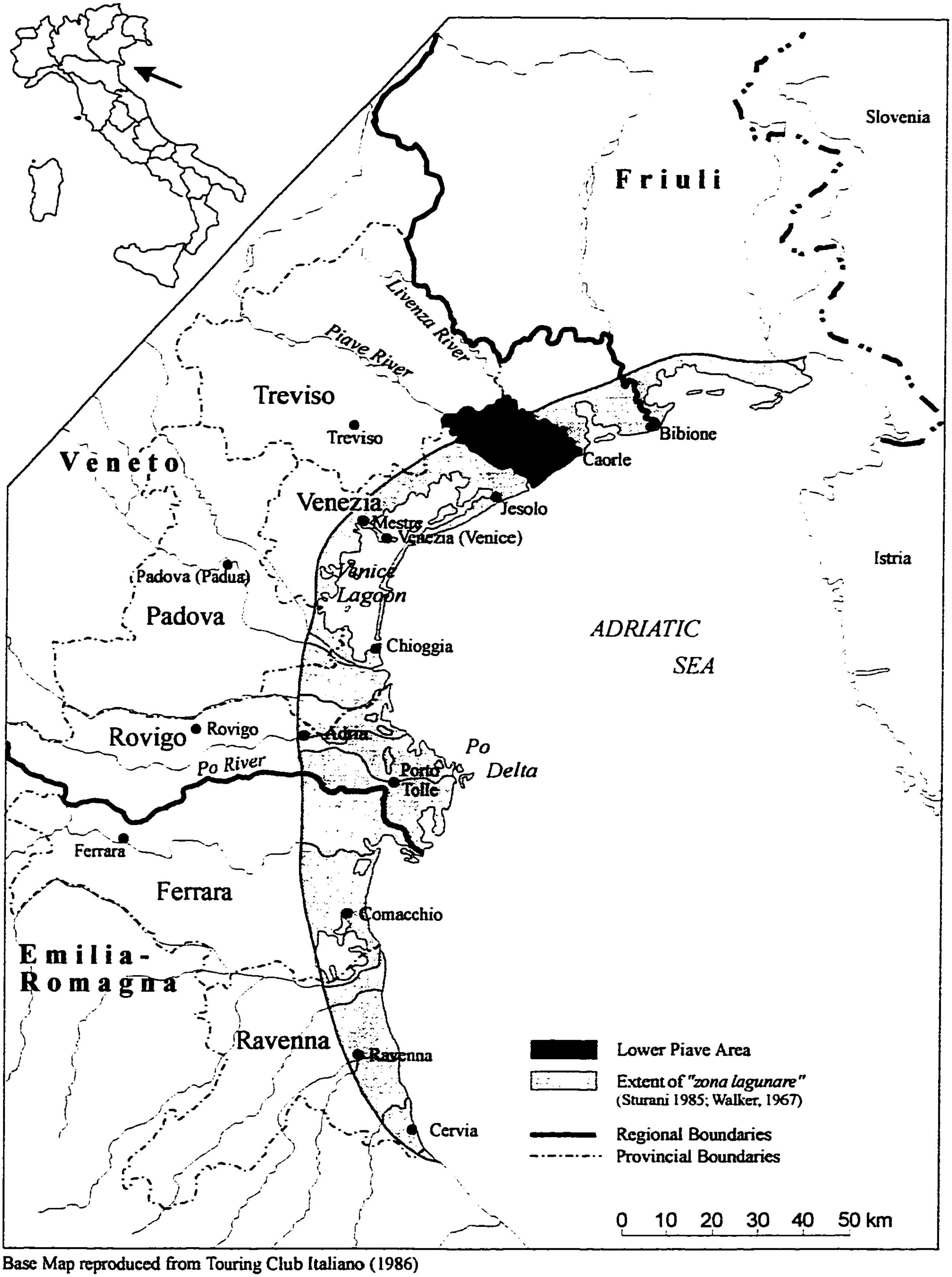
3.2 LOWER PIAVE CASE STUDY AREA

The Lower Piave area lies within the broad northeastern Italian coastal belt described in Chapter 1 and illustrated in Map 1.1. The Lower Piave area within the overall coastal zone is illustrated on Map 3.1. A smaller study area has been chosen because the entire northeastern Italian coastal zone is too large for a focused landscape analysis.

This particular study area, lying northeast of Venice, has been chosen for a number of important reasons (as opposed to other areas in the coastal belt). One is that it avoids the Po Delta and Venice Lagoon areas, which are areas of extreme complexity from a landscape standpoint. The Po Delta area is of particular complexity because while it has been largely reclaimed for agriculture, its coastal fringe is a relatively unstable area of continuously evolving marshes, sand dunes and spits. The fact that the delta is still growing sets it apart from other reclaimed areas of northeastern Italy, where the natural geomorphologic processes have largely been halted by humans. The smaller study area also avoids the Venice lagoon, which is another biophysical context altogether. Its present day physical form was influenced in an earlier era by the needs of the city of Venice and the former "Serene Republic".

Finally, there were a number of logistical reasons for selecting this particular area. One major consideration is the author's geographic and cultural familiarity with the region given his Venetian cultural roots. The study area was practical to investigate from a logistical point of view

Map 3.1: Lower Piave Area



Base Map reproduced from Touring Club Italiano (1986)

as it is geographically close to the cities of Padua and Venice. They are home to regional universities and government departments which provided most of the data and information used in this project. The **University of Padua** also served as the "home base" for this project. Moreover, the Lower Piave area falls within the jurisdiction of one particular land reclamation bureau (*Consorzio di Bonifica Basso Piave*)[1]. The *Consorzio* and its individual basins are depicted in Map 3.2. This is a very important factor because land reclamation bureaus are a key source of historical, environmental and ecological information.

It should be emphasised that the Lower Piave area is neither a political nor administrative region, nor a rigidly defined region. It is a roughly rectangular parcel of land bordered on parallel sides by the Adriatic Sea and the Venice provincial boundary[2], and the Livenza and Piave rivers. The size of this rectangle is comparable to a township in southern Ontario.

This specific configuration has been defined as the study area for a number of reasons. First of all, the area lies mostly within the former *zona lagunare* (depicted in Map 1.1). The upper boundary of the Lower Piave roughly corresponds to the sea level elevation contour. This more or less forms the natural boundary between the *terraferma*[3] and the *zona lagunare* within the Venetian Plain. The zero metre line and general elevation contours within the Venetian Plain are illustrated in Map 3.3. Land elevations within the Lower Piave are illustrated in Map 3.4. Elevations in the Lower Piave range almost entirely from 5 metres above sea level to 5 metres below sea level (Fassetta, 1977). The Piave and Livenza rivers are higher than much of the

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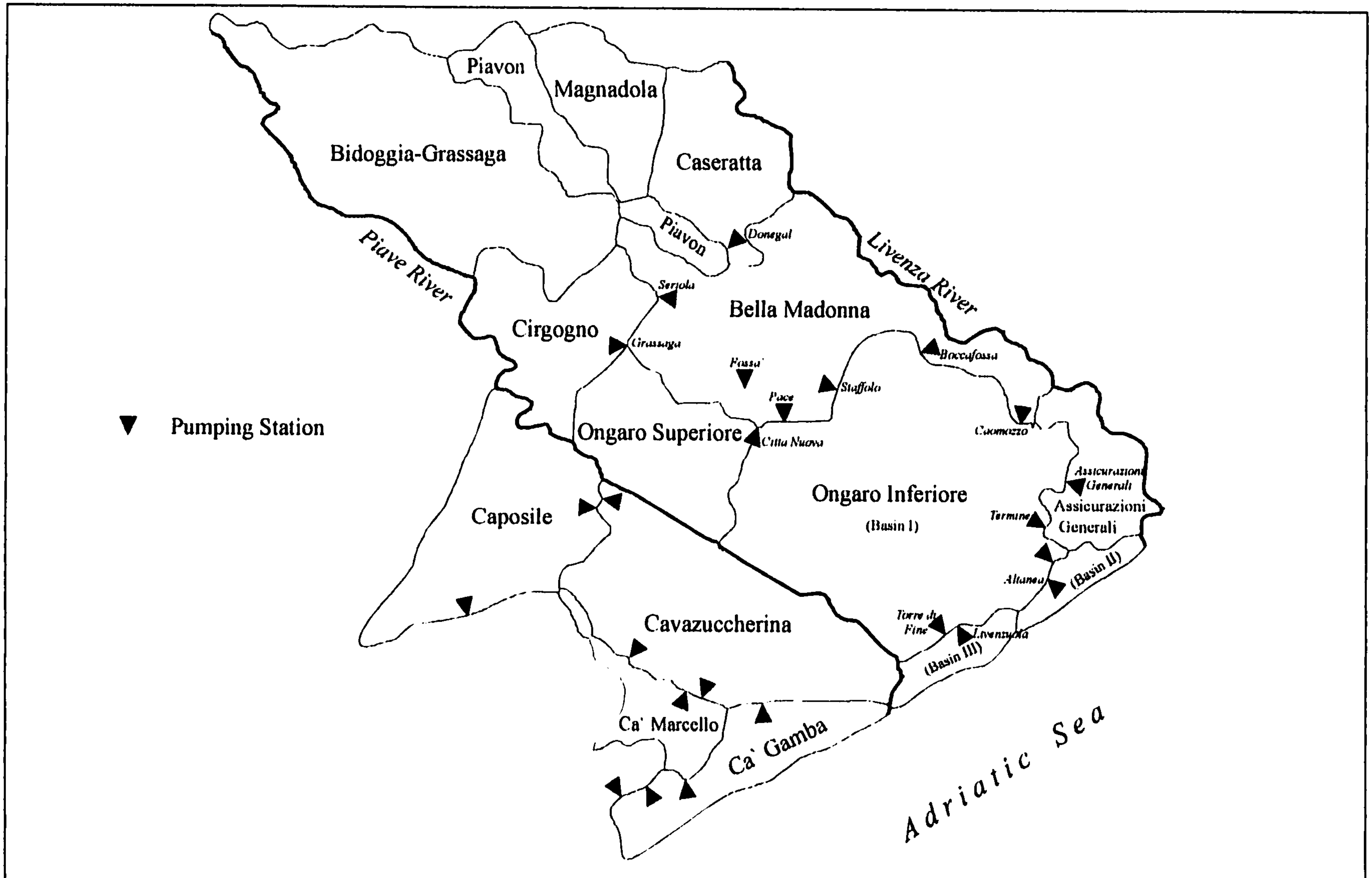
[1]In Italy, reclaimed areas have been placed under the management of land reclamation bureaus. These are quasi public bodies charged with maintaining and managing reclaimed areas. The *Consorzio di Bonifica Basso Piave* represents a union of 13 smaller *Consorzi* occurring in 1936. A further description of their evolution is found later in the chapter.

[2] The study area being partially delimited by an administrative boundary is an important consideration given that most of the agricultural data used to analyse the evolution of agriculture is aggregated according to municipal and provincial administrative divisions.

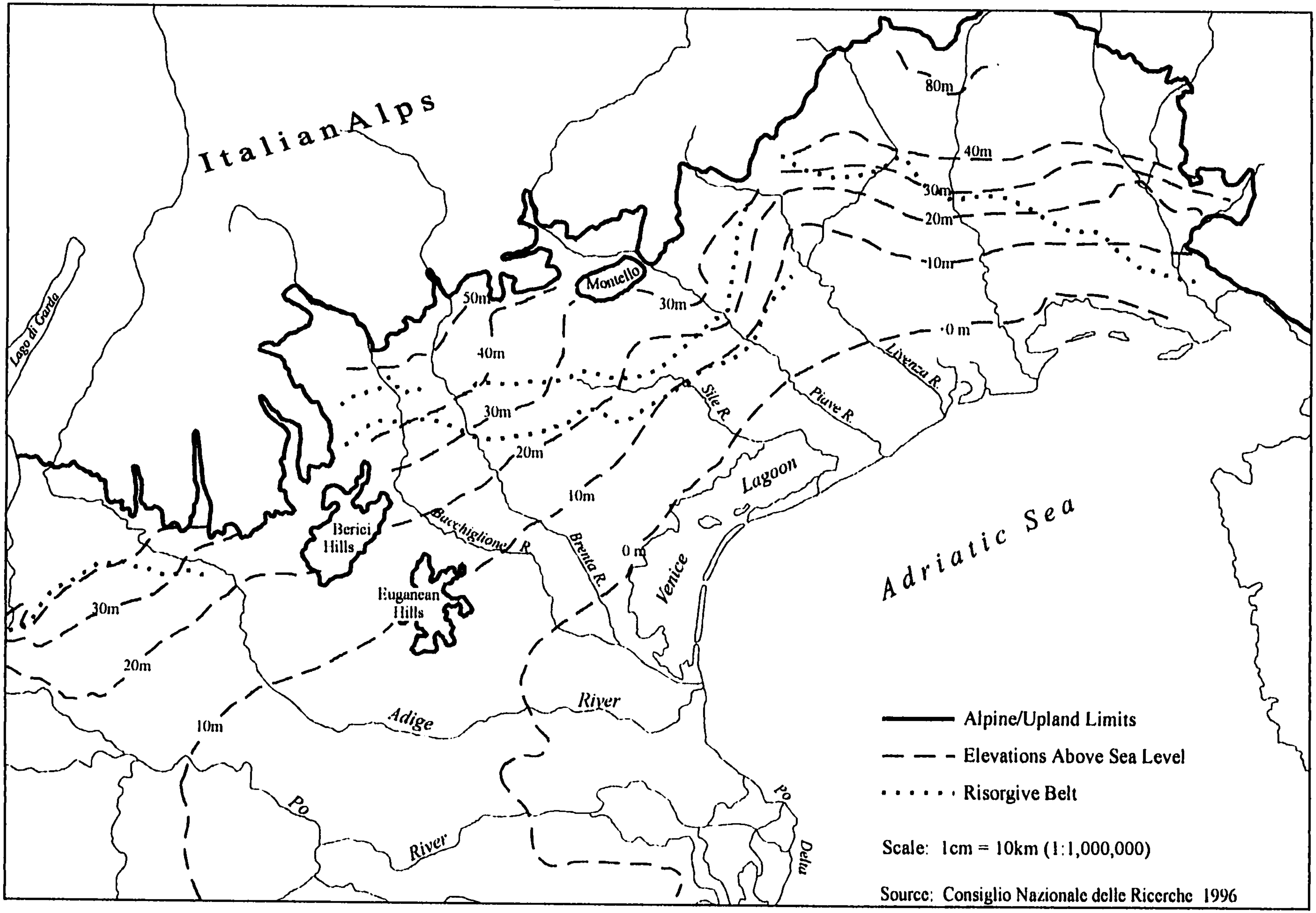
[3]Term refers to the land-based Venetian hinterland.

Map 3.2: Basins of the *Consorzio di Bonifica Basso Piave*

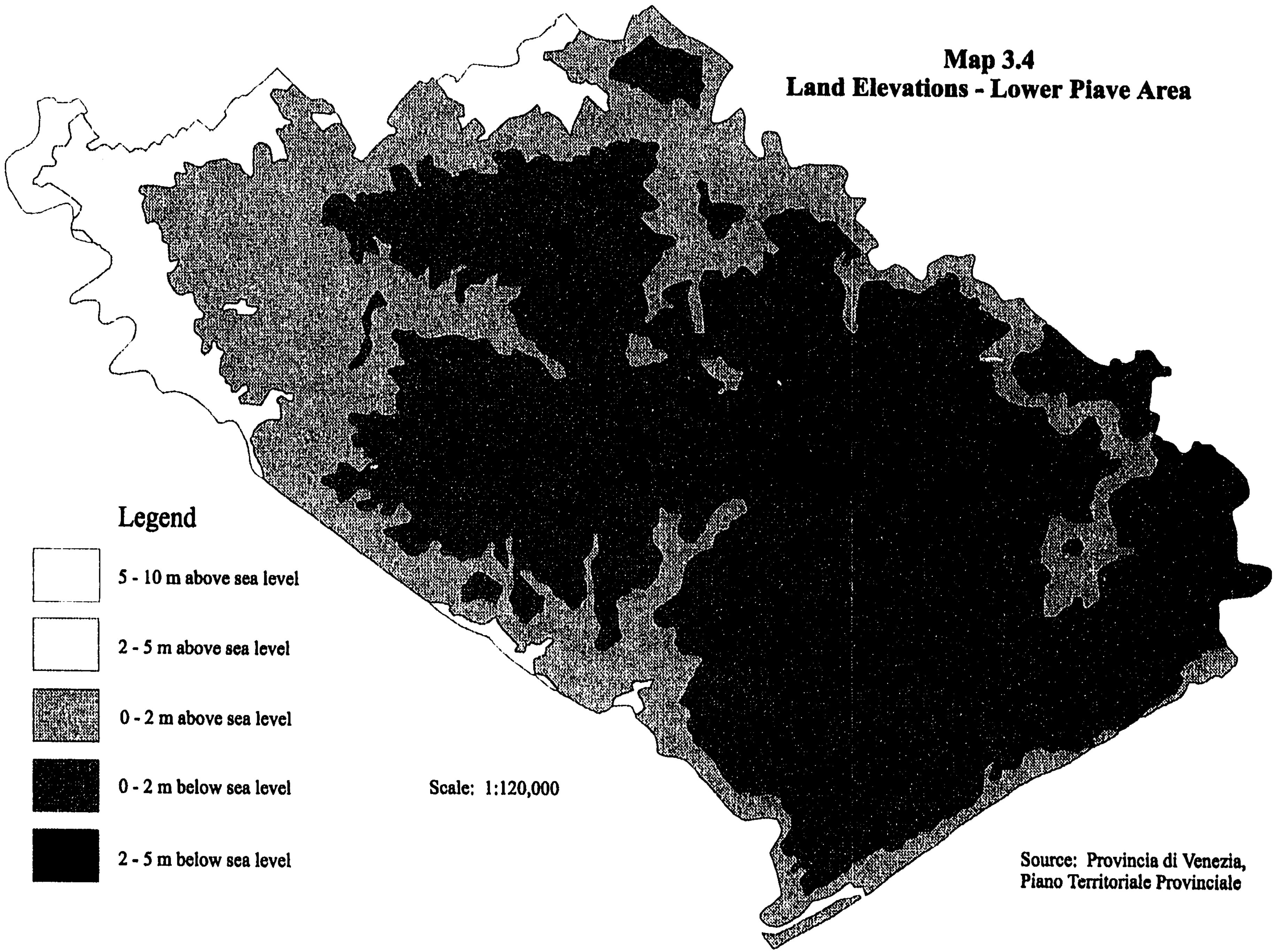


Sources: Fassetta 1977; Provincia di Venezia 1993; Consorzio di Bonifica Basso Piave 1991

Map 3.3: Venetian Plain



Map 3.4
Land Elevations - Lower Piave Area



surrounding terrain[4].

The low elevations combined with the diking of the lower courses of the Piave and Livenza rivers (see section 6.3) means that the Lower Piave falls almost entirely within an internal watershed. The condition of an internal watershed requires a system of canals and pumping stations to drain all surface water in the study area. An internal watershed thus forms logical unit of investigation given it constitutes a particular landscape unit that is physically confined by topography and tied together by an artificial drainage system. The drainage system is the most crucial aspect of land governance as it would be in all sub-sea level reclaimed landscapes.

The study area also contains a cross-section of older governed landscapes and more recent highly governed landscapes. In the upper part, just to the east of the Piave River, are found older landscapes with remnants of original Roman influences. Roman influences are discussed in the next section, as well as their significance in relation to landscape health. The reclaimed highly governed landscapes created in the 20th century provide the basis for landscape health investigation and interpretation. Some graphic illustrations of these landscapes are found both in this chapter and later in Chapter 6

[4]The low and sub-sea level elevation of much of the Lower Piave means that the lower courses of the Piave and Livenza rivers are generally higher than the surrounding terrain. This has been the case for may years. Bertolini and Rinaldi (1934) noted that prior to reclamation of its marshes, the beds and banks of major channels and rivers in the area were actually higher than the surrounding marsh areas because of constant sediment deposition along their banks. Reclamation and the building of dikes reinforced this arrangement.

3.3 LANDSCAPE HISTORY OF THE VENETIAN PLAIN AND LOWER PIAVE AREA

1. Pre-Roman Period

Discussion of this historical period begins from the perspective of geological events given how physical characteristics of the Venetian Plain ultimately provide the setting for future human-driven landscape evolution. The Venetian Plain is part of the broad northern Italian Plain (*Pianura Padana*) which stretches across northern Italy from the cities of Turin to Trieste.

Geologically, the plain is a lowland basin formed primarily as a result of the progressive erosion of the Alps and Apennines (Walker 1967). These mountains are composed of a variety of crystalline, sedimentary and metamorphic rocks (Touring Club Italiano 1986). The plain consists of various layers of sands, gravels and clays overlaying bedrock. These deposits reach a depth of up to 3000 metres in some places. The earliest deposits date back to the Pliocene era (some four and one half million years ago), when the area was submerged under a continuation of the Adriatic sea. During this epoch, eroded material carried by surrounding rivers was deposited on the seabed to create the first layer. Further deposits were laid during the Quaternary (one and a half to two million years ago), when the seas retreated and natural processes of erosion continued to erode the surrounding Alpine and Apennine Mountains (Walker 1967).

The youngest deposits of the northern plain are the product of the most recent *Wurmian* period of glaciation (10-18,000 years ago), and the post-glacial alluvial deposits of the plain's rivers (the being the Po). Taking a two-dimensional linear horizontal perspective, the typical substrate pattern from alpine areas southwards to the Po valley is one of a progression from moraines, to gravels, to silts and clays. This is attributable to the natural grading of glacial materials by water. In the *Prealpi*[5] belt are found moraines formed from glaciation. Just south of

[5]Refers to the belt immediately adjacent to Alpine areas. Similar to a "piedmont" or "foothills" belt.

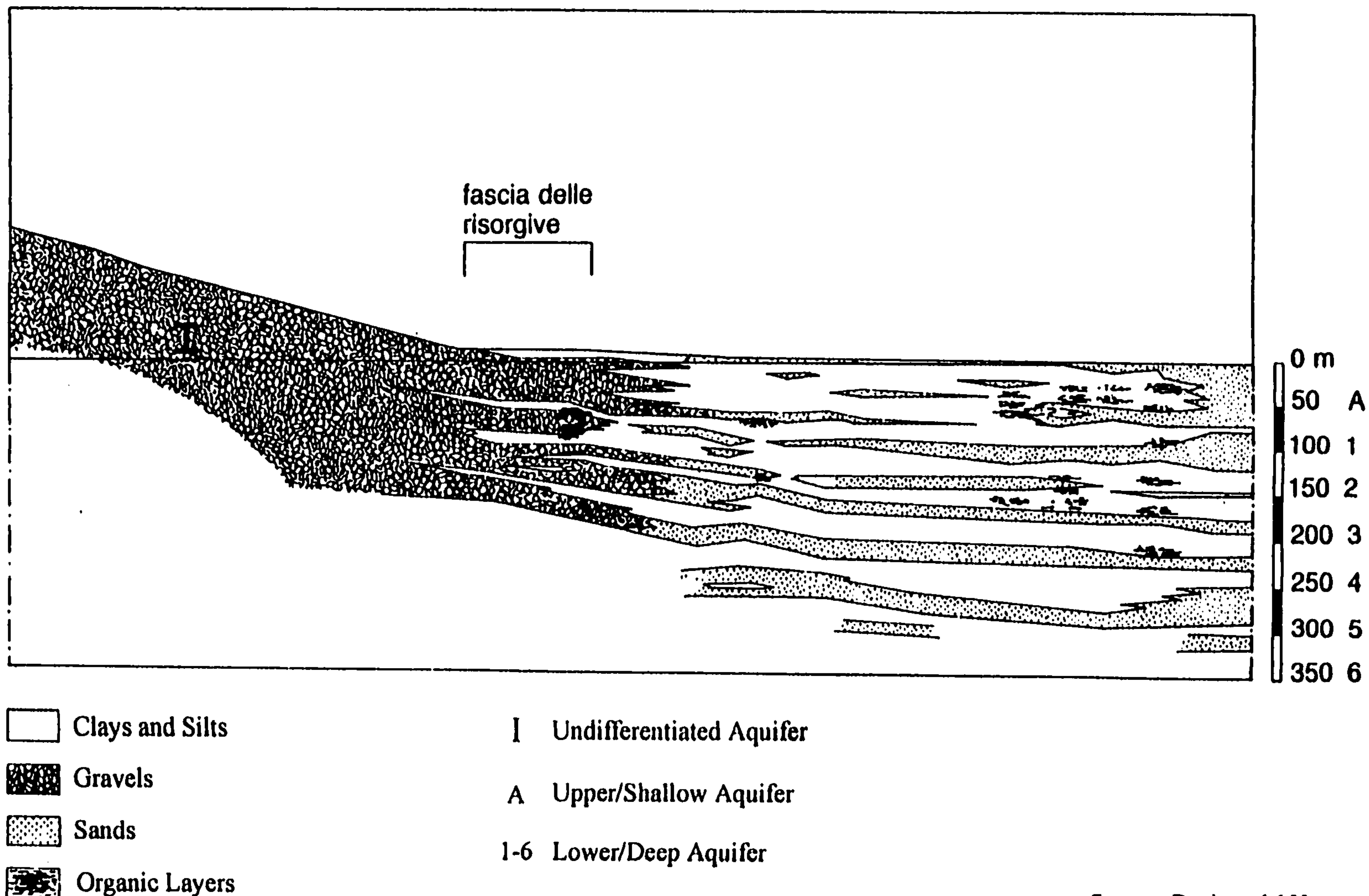
the moraine belt, on what is called the upper plain *(alta pianura)*, is found an almost continuous belt of predominantly gravel material formed by the spread of outwash fans by glacial meltwaters. Towards lower elevated portions of the plain, and in the Po river valley in particular, are found finer materials (silts and clays). This pattern is also characteristic of the entire Venetian plain. A two-dimensional vertical perspective of Venetian Plain substrates is provided by Figure 3.1.

This pattern is less characteristic south of the Po Valley up to the base of the Apennines. Here, moraines are less frequent given the Apennines were less severely glaciated than the Alps. The upper substrate profile consists of sands, silts and clays (Walker 1967; Consiglio Nazionale delle Ricerche 1996). In recent times, sediments eroded from deforested mountain slopes have augmented alluvial deposits along the lower portions of the plain and coastal areas (Walker 1967). Among other things, this phenomenon has led to a rapid extension (in geological terms) of the coastline into the Adriatic. The progression of the coastline has been illustrated in Map 1.1.

The Venetian Plain (Map 3.3) gently rises from sea level to an elevation of about 80-100 metres over a maximum distance of about 80-km. Most of the plain, however, rises gently from 0 to 40 metres above sea level followed by the more rapidly rising *Prealpi*. The plain is divided into an upper plain *(alta pianura)* and a lower plain *(bassa pianura)*. The division between the two is roughly marked by the line of *risorgive* which is a thin belt of frequent spring and river formation caused by the permeable substrates of the upper plain meeting the more impermeable clay soils and substrates of the lower plain (Figure 3.1). This characteristic has always had significant implications for agriculture in the plain. The permeable soils of the upper plain have always required more irrigation compared to those of the lower plain, while the heavy and impermeable clay soils of the lower plain are poorly drained and have necessitated drainage improvements by humans over the years.

The most recent vegetation succession (or the stage which existed prior to widespread land clearing for agriculture in the Roman era) is thought to have evolved and stabilised after the

Figure 3.1
Hydrogeological Substrates - Venetian Plain



Source: Regione del Veneto, 1988

latest ice age (Wurmian; +10,000 years ago). This occurred roughly between 5500 and 2500 BC with some variations occurring as a result of periodic climatic fluctuations (Zanetti 1995b). The initial vegetation succession profile roughly corresponded to the lines of the region's physiography. The *Pre-alpi* were characterised by mixed forests of mesophilic woods in lower reaches (oak, beech, ash, chestnut, hornbeam), which gradually turned to coniferous forest (spruce, pine, larch) as altitude increased. In the lowland plain, deciduous forests of primarily oak (as well as ash, elm, basswood and hornbeam) predominated in drier areas, while poplar and willow evolved in wetter areas along riverbanks. In coastal areas, xerophilous vegetation would predominate on littoral dunes, where shrubs such as junipers would be followed by arboreal types of oak *(Qercus ilex)* and pine *(Pinus pinea)* woods in some areas (Lorenzoni 1983; Susmel 1994).

The earliest recorded inhabitants of the Venetian Plain were the **Euganeans** (Sturani 1985) and settlement of this area dates back to the Neolithic and Bronze Ages (Walker 1967). The Euganeans were followed by the **Veneti** who descended onto the plain from the Balkans to the east at around 1200 BC. These peoples, who had knowledge of iron forging, subdued the more primitive Euganeans and succeeded in establishing agriculture and settlements such as on the site of present day Padua (Bosio 1984; Sturani 1985). Eventually, the Veneti became allied with the more powerful Romans to ward off invasions from the **Etruscans** to the south, and **Gauls** to the west (Sturani 1985). The end result of the alliance was Roman emperor Caesar granting Roman citizenship to the Veneti in 44 BC (Varagnolo 1991).

It has been hypothesised that before Roman domination, the Venetian plain was an expanse of oak forests and numerous marshes *(acquitrini)* broken only occasionally by small or larger islands of cultivation and meadows, which surrounded nuclear settlements. Inhabitants lived by hunting, gathering, agriculture and pastoralism. The latter two grew in prominence and intensity with the advent of the **Paleoveneti**, and **Roman** civilisations. The only traces of human impacts from this era are the presence of modern towns and cities which grew from original settlements founded during this era (Bosio 1984; Susmel 1994).

2. Roman Era

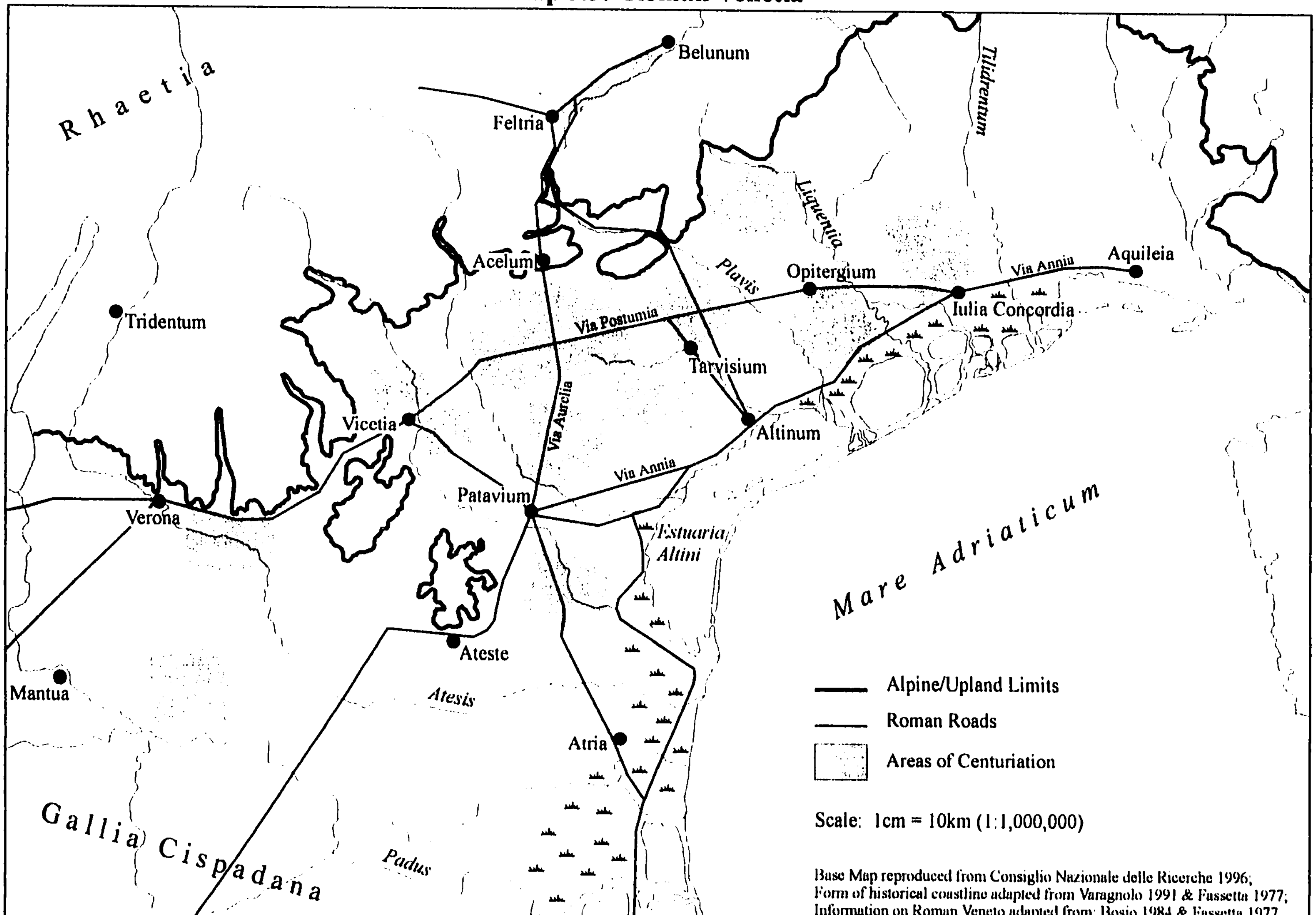
The first widespread and extensive territorial restructuring in the Venetian Plain was initiated during Roman colonisation of the area around 200 BC (Bosio 1984; Provincia di Venezia 1994a). Roman colonisation resulted in the construction of roads, establishment of settlements, and expansion of agriculture. Most major cities within the Veneto region today were significant Roman settlements *(Verona, Vicetia, Tarvisium, Belunum, Patavium)*. Many existing roads occupy tracts of former Roman roads *(Via Annia, Via Postumia, Via Aurelia)* (Map 3.5).

A powerful Roman empire required new lands not only to expand agricultural production to feed growing populations, but also to consolidate control of its territory and serve as staging points for further expansion and defence. Around 200 BC, the Venetian plain was colonised by a population of Roman veterans who established agricultural activities (Bosio 1984; Salmon 1984; Provincia Di Venezia 1994a). The Venetian plain provided not only potentially fertile and easily cultivated (flat) land, but was also a strategic area in that it formed a natural corridor leading to Roman territories in the north and east.

The Romans typically borrowed agricultural methods and surveying techniques developed by ancient civilisations such as the Greeks and Etruscans. The ancient Greeks pioneered the geometric division of cultivated lands into regular rectangular fields or *campi*. They rotated crops with fallow and developed the practice of separating meadows, pastures and commons from cultivated plots using trees and hedgerows. Limits of cultivation and property were defined using hedgerows, walls, ditches, rivers, and roads (Sereni 1961).

The Etruscans are credited with the development of the landscape of the *piantata* where cultivation of grain crops was combined with the cultivation of vines. In this scheme, cultivated

Map 3.5: Roman Venetia



fields were further divided into smaller sub-sections using rows of vines married with trees, which held up the vines[6]. The practice of marrying vines with trees and crops arose out of the need to provide the staple crop of grapes in areas whose conditions were generally unsuitable for viticulture (Sereni 1961). It is significant that many of the practices and landscape elements pioneered by these civilisations have remained part of the Italian agricultural landscape until recent times.

While the Roman era marked the start of extensive settlement and land clearing for agriculture, it is perhaps more significant that the Romans were the first civilisation to systematically manage territory on a large scale by introducing a technique called **centuriation**. Centuriation was the practice where lands opened to agriculture were subdivided into rectangular parcels for the main purpose of political and administrative control of the land. This subdivision was done using a universal measuring scheme and gave a systematic rectangular form to newly colonised areas[7]. Patterns of this form of territorial organisation still persist in much of the present Veneto landscape. This territorial organisation, combined with actions taken to maintain its structures, represents the first time landscape *governance* was implemented on a large scale in the Venetian Plain. In this sense, governance encompassed not only the organisation of territory established by Roman surveying, but also the agricultural and land management methods that maintained its structures (e.g. hedgerows, piantata, systematic drainage).

In the Roman system, territories were organised administratively by their subdivision into *municipiums* (county). At the centre of which existed a *civitas* or town on which a surrounding agricultural grid system or *agra centuriata* was developed. The grid system around a municipum was rationally laid out to take into account both practical and environmental considerations. For

[6]Further illustration of the *piantata* is found during discussion of the Austrian Era.

[7]See Sereni (1961), Tozzi & Harari (1984), Bosio (1984), Schirato (1991), Caravallo & Giacomin (1993), Menegazzi (date unknown), and Provincia di Venezia (1994a).

example, a grid system was usually aligned to take advantage of factors such as slope, drainage, solar position, major watercourses and important roads. The basis of the grid system was individual *centuria* which were rectangular parcels of land normally measuring 20 *actus*[8] or a standard measurement of 710 metres a side[9]. The dividing lines were known as *decumanis* and *kardo* (or cardines), which proceeded in an E-W and N-S direction respectively. Individual centuria would be further subdivided into smaller plots by parallel or perpendicular *limites intercisivi* and *inner interlimites*. These parcels were allotted to the veterans according to their rank.

An illustration of this typical centural model is depicted in Figure 3.2. The criss-crossing of decumani and cardine axes within a municipum gave the landscape its rectangular form. This also provided the grid for the road and drainage network in the region. Along with territorial organisation, the Romans sought to control and facilitate drainage by constructing ditches and canals. In many areas of the Venetian plain, the roads and canals which followed the Roman decumani and cardines are still present today.

Roman agricultural practices followed the agricultural techniques known at the time, which were based on the necessity of balancing production with the maintenance of fertility. Thus cultivators followed a two or three field rotation of crops (grains and fibres such as linen) and fallow, or crops, leguminous plants and fallow[10]. The Roman agricultural landscape was one of commons and closed fields *(campi chiusi)*, as hedgerows lined the major decumanus and cardine axes, and formed the *limites intercisivi* and inner *interlimites*. Ever present ditches and paths usually accompanied hedgerows. Individual fields were also demarcated or separated using paths

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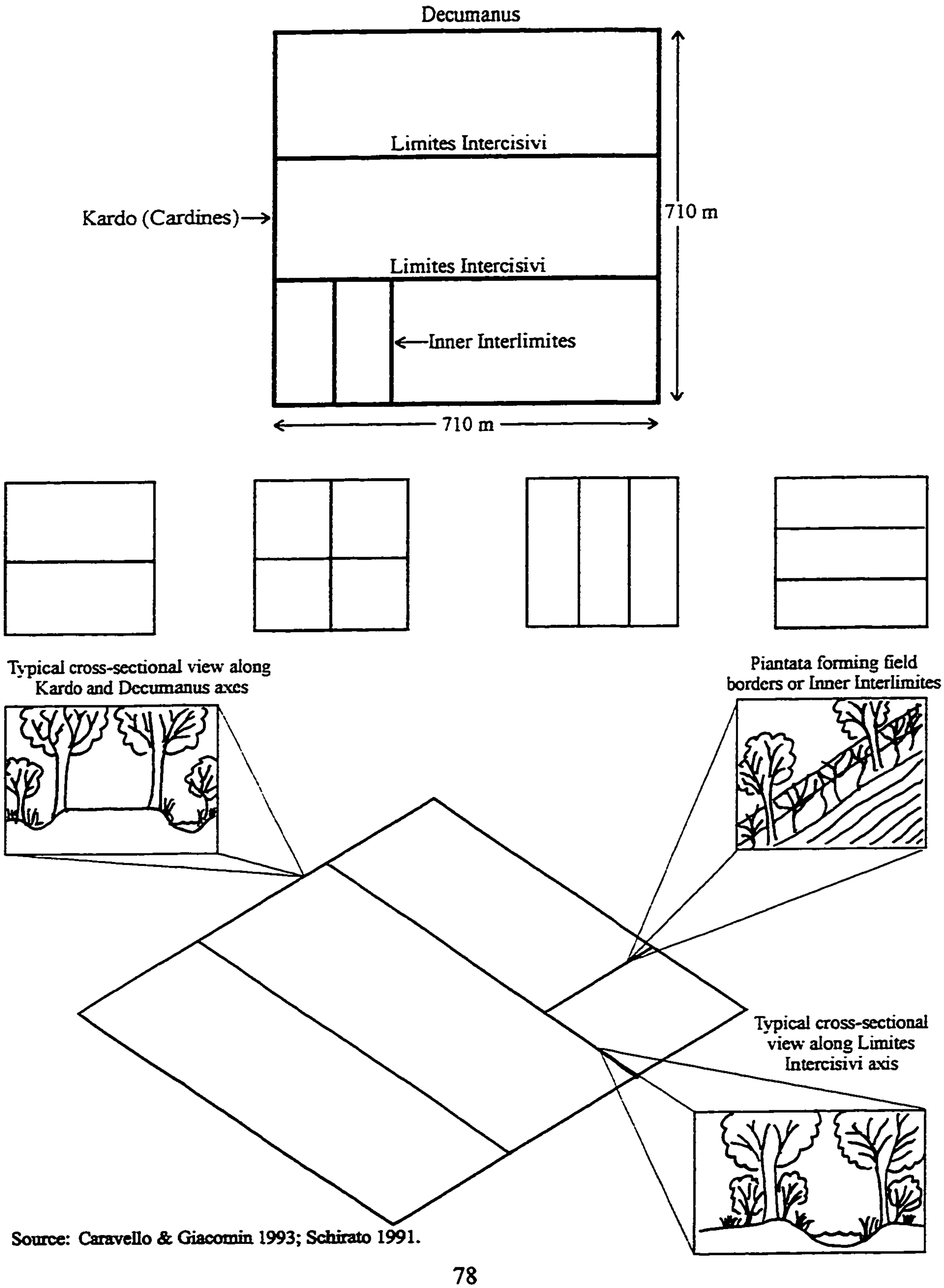
[8]One square actus, or 1261.67 square metres was considered half a yoke of land, or as much as one yoke of oxen(2) could plow in half a day (Caravello & Giacomin 1993).

[9]One actus measured 35.52 metres. Dimensions of Roman decumani and cardines did vary throughout the empire from 15 to 40 actus. See Menegazzi, Provincia di Venezia (1994a) and Tozzi & Harari (1984).

[10]In E. Ragni's: *"L'Agricoltura Romana nell'Eta` Imperiale"* (1987), as cited in Schirato (1991).

Figure 3.2
Centural Models



Source: Caravello & Giacomin 1993; Schirato 1991.

and rows of trees married with vines *(piantata)* (Schirato 1991; Sereni 1961). Hedgerows served many important practical purposes. They demarcated the limits of fields and property, and kept grazing animals out of the commons. They provided fodder for animals and edible products for humans as well as habitat for wild game. They protected against erosion along ditches and provided wood for fuel and building materials required by self-sufficient farms.

Archaeological and territorial evidence of Roman centuriation is widespread throughout former Roman territories in Europe and North Africa (Caravello & Giacomin 1993), and especially in the Venetian Plain (Bussi & Vandelli 1984; Schirato 1991; Caravello & Giacomin 1993). Significant areas of centuriation existed around present day Verona, Vicenza, Padua, Castelfranco-Asolo *(Acelum)*, Treviso, Belluno, Oderzo *(Opitergium)*, Portogruaro *(Iulia Concordia)*, and now defunct Altino *(Altinum)* (Map 3.5). In areas around Padua and Castelfranco, especially, the centuriation grid has remained almost entirely intact as present day roads, canals, and fields more or less follow the grid system imposed by the Romans 2000 years ago.

Close examination of the area once occupied by the *Acelum* centuriation reveals that much the present day network of roads, paths and canals closely resembles the 710 by 710 metre square centuria imposed by the Romans (Furlanetto 1984; Schirato 1991; Caravello & Giacomin 1993). Furthermore, the study by Schirato (1991) demonstrates, through the use of air photos and ground survey, that original *limites intercisivi* and *inner interlimites* of one centuria are still occupied by hedgerows and ditches which suggests that the original Roman landscape elements have been perpetuated to this day. Unfortunately, vegetation has decreased substantially since the first aerial survey in 1955 so that it cannot be used to the same extent as a measure of centuriation.

The centuriation of particular interest to this study is the area around Oderzo *(Opitergium)*, which is believed to have begun around the 1st century BC. The southern limits of this centuriation overlap the northern portion of the Lower Piave. Some axes of 20x30 or 20x15 actus centuriation are visible today in the form of road and drainage patterns (Figure 3.3 on next page) (Rigoni 1984; Tozzi & Harari 1984). Noteworthy is the fact that this area of centuriation terminated along the line where the *terraferma* bordered the marshy coastal belt. This is also roughly the path of the *Via Annia* which ran precariously[11] along the northern fringe of the marshy coastal belt from now defunct *Aquileia* to *Altinum*.

Evidence regarding Roman settlement and use of the marshy coastal region around the Lower Piave area is sketchy. While the southern boundary of centuriation suggests that Roman colonists generally stayed away from the inhospitable coastal area, Roman archaeological sites and ruins are scattered across the marsh belt. The Romans had also founded major port settlements in marshy coastal regions of northeastern Italy *(Aquileia, Altinum, Adria, Ravenna)*; some of which remain to this day *(Ravenna, Adria)*. Furthermore, the noted geographer\philosopher, *Plino*, recorded that a port existed at the mouth of the Livenza river. Therefore it is generally accepted that there was some settlement in the coastal margin (Tozzi & Harari 1984). However, with few exceptions, Roman settlements did not survive in the inhospitable marshy areas and no lasting imprints remained.

The Roman era is probably the most important period in the transformation of the Venetian plain from a "natural" landscape to a cultural landscape. Through their social, economic, cultural and technological practices, the Romans modified the natural landscape and laid the foundations for what would become the "traditional" cultural landscapes of the Veneto. In terms of the scale of physical modification, it is very difficult to precisely estimate the size of territory which was converted to agriculture. What can be concluded from available evidence of centuriation and Map 3.5 is that large areas were converted to cultivation. Conversely, large tracts of forests and marshlands remained as centuriation did not cover the entire plain.

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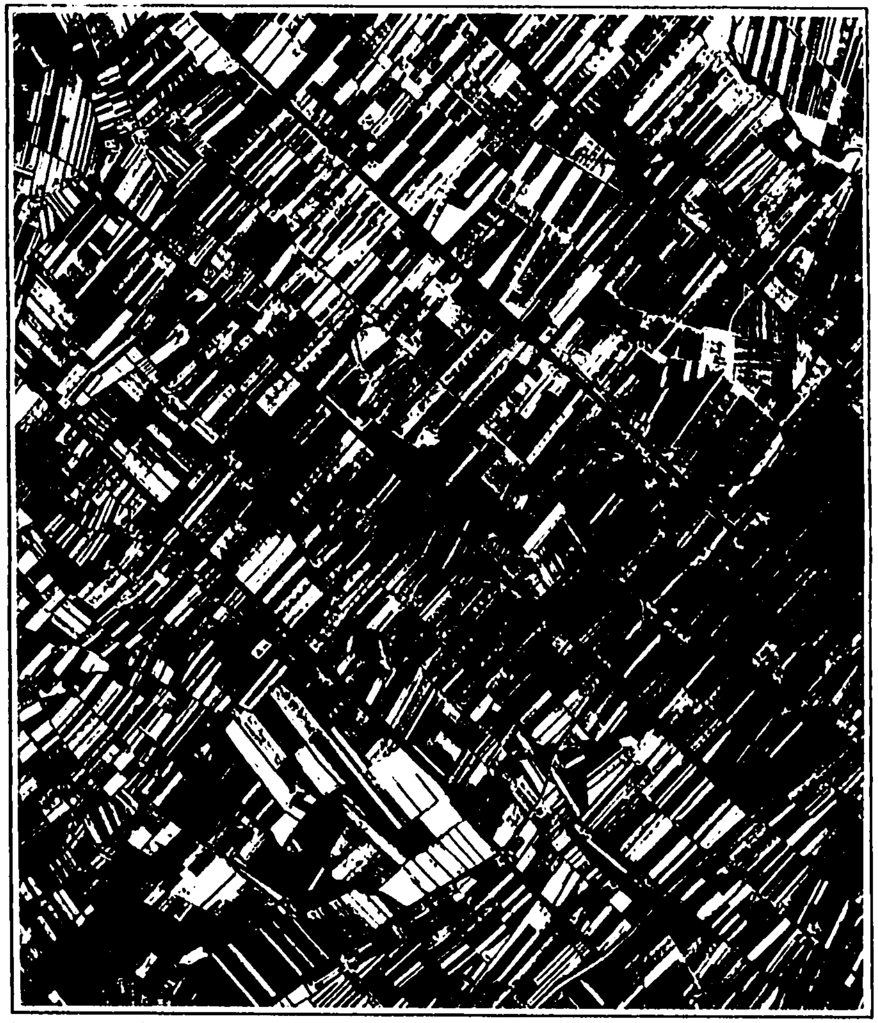
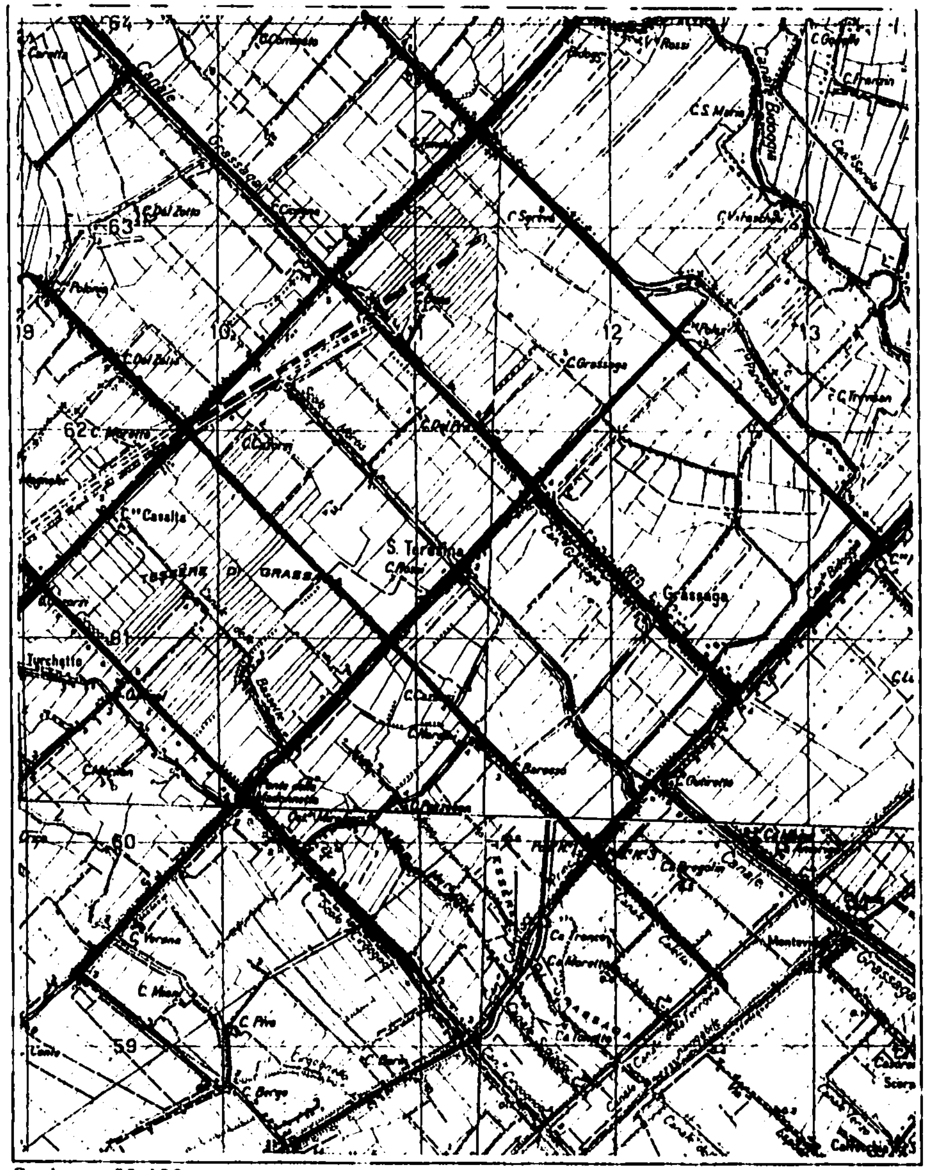
[11]Tozzi & Harari (1984) write that the *Via Annia* was difficult to maintain as it was frequently damaged or washed away by the frequent inundation and meandering of river channels.

Figure 3.3: Cartographic and Photographic Images of Lower Piave Centuriation Remnants



Sources: Istituto Geografico Militare - 1:33,000 air photos (1954); 1:25,000 series topographic maps (1960's edition)



Scale: 1 50,000

More important than the actual area converted to agriculture, however, were the precedents established by the Romans (Bosio 1984) and their indelible imprint on the landscape, which has survived to this day. Socially and economically, Roman organisation marked a new chapter of relations between humans and the landscape through the establishment of colonies centred around settlements, and the systematic allotment of land to individual and independent farmers. Culturally, their practice of territorial organisation and restructuring, such as the construction of canals and land reclamation, established the precedent that humans could exert some control on nature for their own benefit.

Sereni (1961) has called the persistence of Roman era landscape structures "the law of inertia". Once a determinate form is fixed on a landscape, it tends to perpetuate itself, despite the loss of the original factors which created it, until new technologies and cultural developments become strong enough to upset this balance. Detailed studies of centuriated areas (Schirato 1991; Caravello & Giacomin 1993) suggest that their dimensions and layout conformed to an ecological structure which balanced the needs of agriculture, self- sufficiency and ecology. This, combined with relatively environmentally benign agricultural technology practised over the centuries, led to a long term viability with respect to the preservation of vegetation structures (hedgerows) and floral and faunal diversity.

It is only with the onset of modern industrial agriculture with its preference for large and unobstructed fields that this ecological balance has been disrupted. Thus the ingenuity and intentionality of the Romans, and resulting long term viability of their landscapes, is an undoubtedly useful precedent concerning successful landscape governance and the creation of sustainable cultural landscapes.

3. Medieval Era

The widespread decline of *Pax Romana* began during the 5th century when the Romans were no longer able to ward off Barbarian invasions from the north and the east. During the 5th century, the Veneto was repeatedly sacked by successive waves of invading Barbarian tribes including the Vandals, Ostrogoths, Slavs, Visigoths, Huns and Goths. This proceeded to shatter the unity of Italy and the Empire so carefully built up by the Romans (Sereni 1961; Walker 1967; Sturani 1985; Provincia di Venezia 1994a). Thus, the Roman era of relative peace, stability, and cultural advancement gave way to an era of periodic invasions bringing death and destruction. This bleak period would last until the end of the 10th century and the unity of the Italian peninsula would not be recaptured until the establishment of an Italian state in 1861.

Frequent Barbarian invasions devastated the urban and rural life established in the previous era and gradually unleashed long term social, cultural and landscape change. Cities suffered frequent sacking, death and devastation from invading tribes. While most cities in the plain recovered from the destruction, some such as *Aquileia* and *Altinum* disappeared forever (Walker 1967). During this era cities became self-contained walled fortresses preoccupied with protecting themselves from the invading tribes. Rural areas became depopulated as most of the Roman population fled to more protected cities, hilly areas, or to islands in the Adriatic coastal area where the impenetrable and inhospitable terrain provided little appeal for land based invaders. Rural depopulation and the devastation of cities, which diminished their control over the countryside, had a profound impact on rural landscapes. Except around cities and monasteries, large tracts of cultivated land were abandoned and reverted to pasture and open fields.

The vast oak forests, which had been reduced during Roman colonisation and expansion of agriculture, made a gradual comeback on much of the abandoned land (Susmel 1994). The early medieval rural landscape was one of large tracts of forests and expansive meadows open to hunting and pastoralism. This was interrupted only occasionally with plots of cultivation which were under constant threat from grazing animals (Sereni 1961; Provincia di Venezia 1994a).

While agriculture did not vanish, the only areas where intensive cultivation was maintained was close to, or within the walls of cities. Here, the model of cultivation was more that of the Mediterranean garden of vines, orchards and garden crops rather than the field crop and pasture system employed by the Romans. In more remote fields, inferior grains requiring less attention, such as sorghum, rye, and barley, were grown in place of wheat to feed the peasantry (Sereni 1961). The form of the agricultural landscapes of this era is illustrated by the depiction in Figure 3.4, which shows a closed field landscape adjacent to a walled town.

The partial conquest of Italy by the *Longobardi* or Lombards in 568 AD entrenched social and cultural changes which had already begun during the waning years of the Roman empire. The Lombards established their presence by overrunning and controlling the major cities and driving out established Romans, many of whom fled to settlements in the Venice lagoon (Provincia di Venezia 1983; Sturani 1985; Varagnolo 1991). As a means of control and food production, the Lombard nobility imposed feudal property and productive relations on surviving populations (Sereni 1961).

The end of the Barbarian Invasions was followed by the rise of the autonomous city-state around the 11th century. At this time, the principal cities of the region controlled adjacent territories which were the precursors to the present day provinces. This era was one of relative peace which saw the re-population of the countryside, the reconstruction of villages and rural infrastructure (dikes, canals, reclamation, roads), and the proliferation of new villages across the *terraferma* portion of the plain. Much of the reconstruction was guided by the Catholic Church, which remained the only binding institution in the absence of unified political control (Sereni 1961; Walker 1967; Provincia di Venezia 1994a).

During this period, large land estates controlled by the church and aristocracy became the

Figure 3.4
Closed Fields - Late Medieval / Early Renaissance Period

Source: Sereni, 1961

norm, and feudal property and productive relations became entrenched. The re-population of rural areas saw the return to cultivation of much of the countryside. Piantata, crop rotation and the growing of wheat in enclosed fields made a gradual comeback at the expense of pastoral activities. However, productivity was kept low because of the limited use of nitrogen fixing forage crops. Also, closed field cultivation regimes continued to remain concentrated around cities and towns, while pastoral activities, which served the valuable function of animal fertilisation, were pushed out to more remote and under populated areas. The peasantry thus continued to rely on pastoralism and poorer quality grain crops for sustenance (Sereni 1961).

In terms of human imprints on the landscape, the Medieval era was largely a period of reversal from the order imposed by the Roman organisation. It was only from the 11th century onwards that a governed landscape started to emerge (or re-emerge) with the re-colonisation of the countryside and the undertaking of large-scale reclamation and drainage works *(opere di bonifica)* to expand and protect cultivation. It was during this period that the today's hydraulic system of diked rivers, drainage and irrigation canals was initiated on the northern Italian plain, and Po Valley especially (Sereni 1961; Provincia di Venezia 1994a).

The Venetians, in particular, became actively involved in reclamation and hydraulic restructuring with the intention to develop agriculture on their hinterland, control frequent flooding and to preserve the strategic integrity of their lagoon. During the second half of the 12th century, Venice established the *Provveditori*. This was a body responsible for planning and overseeing hydraulic restructuring and reclamation. These projects were undertaken largely on a voluntary basis by large individual landowners. This unless ordered to by the state in the case of works crucial to the interests of the state, in which case it would allocate funding (Provincia di Venezia 1983; Cosgrove 1990). During this era, the coastal marsh areas of the Lower Piave were largely left alone with the exception of small settlements in areas of higher ground, such as the ancient town of Eraclea, whose inhabitants relied largely on hunting and fishing activities (Fassetta 1977).

4. Venetian Era

The rise of the city-state not only spurred the great land reclamations of the later Medieval and Renaissance eras; it also corresponded with the rise of the Venetian Republic. This would come to dominate the Venetian Plain from the 15th century until its fall in 1797. The relative isolation and protection provided by the Venice lagoon allowed the original settlers of its islands to exploit their position and develop a civilisation based on the control of maritime trade in the Adriatic and eastern Mediterranean.

Around the start of the 15th century the Venetian nobility cast its eye toward the acquisition of lands on the plain. This occurred as their control of Near East trade routes, and thus their maritime wealth and power base, weakened in the face of challenges from the Turks and other European nations. From 1400 onwards, the Venetian nobility went on to acquire most of the lands in the surrounding Venetian Plain. The Republic then became a land-based power effectively controlling the territory extending from the Po river to Istria in the east (Walker 1967; Provincia di Venezia 1994a). The rise of Venetian control of its hinterland *(terraferma)* resulted in gradual but profound changes to its social and economic organisation, terrain and landscapes.

The acquisition of smaller holdings by the Venetian merchant class during the 15th century resulted in the decline of the large feudal land estates. This effectively began the transformation of the rural economy from a feudal and mercantilist system to a capitalistic economy. This economic form became entrenched in the 16th century. The early capitalistic rural economy was economically unorganised and fragmented as production was based on a large number of smaller, independent holdings controlled by different sectors of society including the nobility, mercantile classes and emerging independent landowners. The 17th and 18th centuries became the era of the

Venetian villas, which evolved from places where the nobility would retreat for pleasure and relaxation, to full-scale productive farms (Provincia di Venezia 1994a). The chief vehicle of production was more or less based on the *mezzadria*. This was a form of socio-economic organisation which combined the repressive structures of feudalism with capitalist modes of production[12].

Over the period of Venetian dominance, the landscapes and terrain of its terraferma were indelibly transformed. While the processes of landscape transformation occurred over 5 centuries, an important snapshot of the contemporary Venetian terraferma was produced by noted Venetian cartographer *Cristoforo Sorte* in 1556 (Archivio di Stato di Venezia; Romanelli & Moreschi 1984). This is depicted in Figure 3.5. This map or illustration was commissioned by the Republic as part of its water management activities, and provides a "bird's eye view" of the territory of the *Trevigiano*[13] (including surface hydrology). It also illustrates important landscape features which tell us much about the terrain existing during this period.

Sorte's map illustrates the surface hydrology of the region. Human interventions are evident during a period characterised by large scale intervention in hydraulic restructuring in order to achieve varying goals including the reduction of hydraulic risk, the preservation of the Venice Lagoon, and the improvement (or *bonifica*) of lands to expand agriculture and feed a growing population.[14] This example illustrates the large-scale landscape of governance achieved by the Venetians. The Piave river is shown flowing across the top of the region, which on the map

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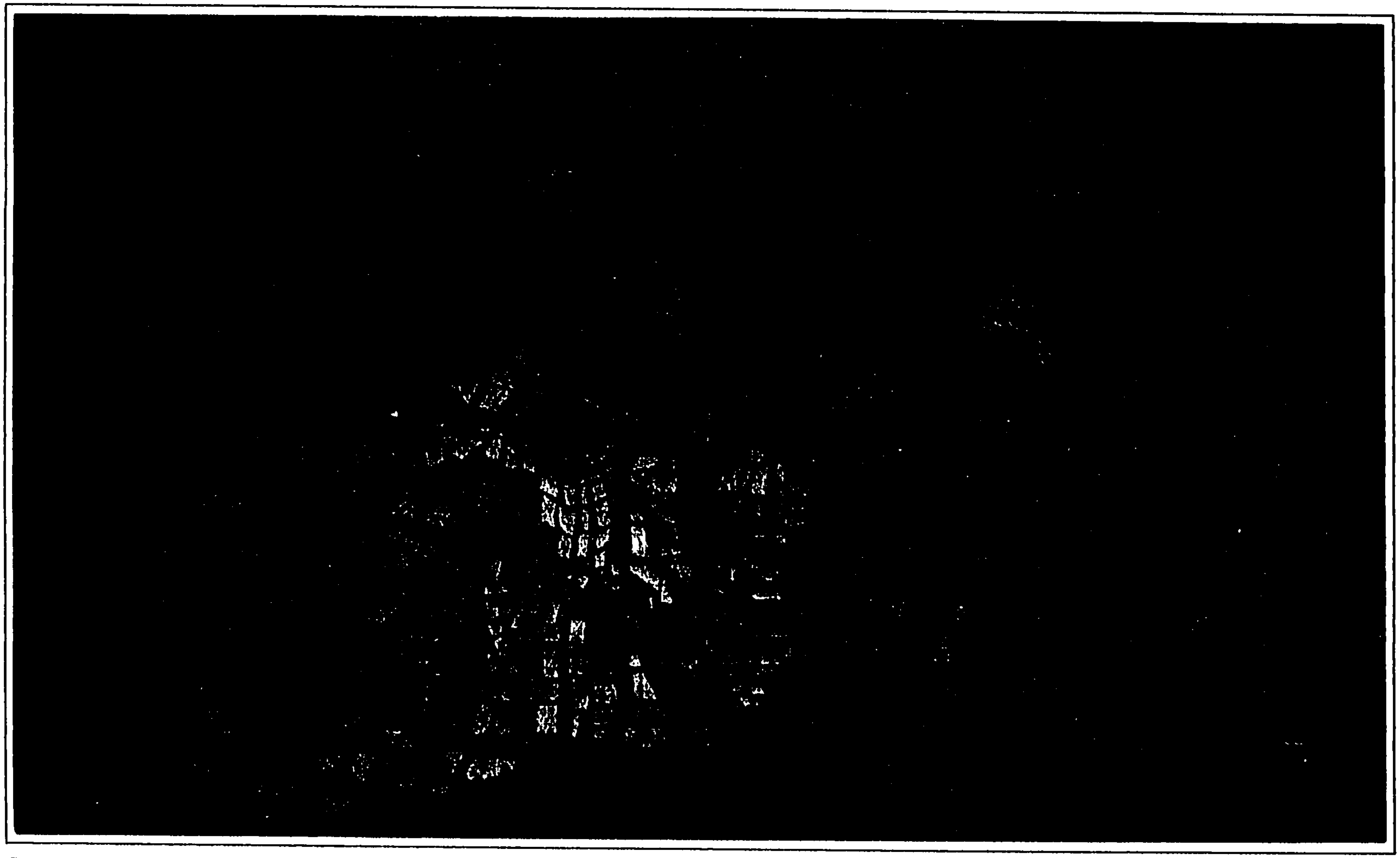
[12]Under this system large estates would be subdivided into smaller parcels (*poderi*) and allocated to peasants who would colonize and farm the land. In return, the peasant would remit a prearranged portion - usually one half - of all production of crops and livestock to the landowner. This was viewed as a proportional way to divide capital, supplied by the owner, and labour supplied by the peasant (Marian 1993).

[13]Or Treviso province. Location of modern day Treviso province is shown in Map 3.1. The circular shaped *Montello* in the centre of Figure 3.5 can be located on Map 3.3.

[14]During the 16th century Venetian landowners were organized into *consorzi* which were the forunners to the modern day land reclamation bureaus which currently administer reclaimed lands in Italy. Under this scheme, property owners affected by, or benefitting from reclamation, were united and obliged by the Republic to help pay costs and deliver manpower.

Figure 3.5: 16th Century Landscapes of the Trevigiano



Source: Archivio di Stato di Venezia

extends from the *prealpi* belt to the marshy areas of the Adriatic coast (bottom right corner). Two major canals extending from the upper Piave river were carved into areas of cultivation. They were intended for irrigation of the upper plain. At this point in time the lower Piave and Sile rivers (bottom of map) follow their original course.

During the 16th and 17th centuries, these along with the Po, Adige, Livenza, and Brenta rivers were channelled and diked along their lower courses. The Brenta, Piave and Sile rivers were diverted away from the Venice lagoon in order to protect it from siltation. Between 1565 and 1579, the Piave river was also diverted away from the lagoon by cutting a channel through the adjacent marsh areas to the northeast. The Sile river was at the same time diverted away from the lagoon by diverting it partway through the old Piave river bed into the Adriatic sea. A dike was then constructed between it and the Lagoon (Provincia di Venezia 1994a; Zanetti 1995a).

Reclamation also proceeded along sides of the new channels where natural drainage permitted the fluvial method of reclamation (or *colmata* method). Under this method, areas adjacent to river channels would be enclosed by dikes and then flooded for long periods of time by sediment-laden waters. This action would eventually raise the level of the land. Otherwise, the coastal marsh areas were largely left alone for there was no practical mechanical means to drain low lying areas until the late 19th century.

Another important aspect illustrated by the map is that of wooded areas. Areas of dense woodland are indicated on the *Montello* (an upland plateau), the upland *Asolano* area to the west, and the headwaters of the *Sile* river. These were the only remaining areas with large stands of old growth timber remaining (Romanelli & Moreschi 1984). Towards the Lagoon and coastal area are large tracts of green shaded area. While the lack of detail on the map makes it impossible to draw conclusions regarding vegetation, there were in fact significant patches of forest remaining in this area during the 18th century (Moreschi & Zolli 1988).

Of great significance during the Venetian era was the disappearance of the vast tracts of oak forests, which were still in existence at the beginning of this era (Susmel 1994). While the Venetians understood the concept of forest management and possessed laws to manage use of public and private forests, periodic neglect of laws, flawed enforcement mechanisms, competing interests[15] and the voracious demand for timber and fuelwood conspired to eliminate the forest (Scala 1922). Most significantly, management efforts were likely doomed by the huge quantities of timber needed by the Republic to construct its palazzos and residences; for pilings to support buildings in a city constructed on waterlogged soil; and to supply the Venetian navy (*Arsenale*) with timber for its large flotilla.

In landscape terms, Sorte's map illustrates how the landscape of enclosed fields had returned to the plain at the expense of forest and meadows. Some of the latter two are still evident as open areas on the map. By the end of the 18th century, closed fields and piantata became entrenched on the Venetian landscape. Large land sections subdivided by piantata, and enclosed with poplar, elm and hedge maple trees along ditches, presented a landscape which could be confused with that of a sparse forest (Provincia di Venezia 1994a).

Agriculturally, the era was characterised by the expansion of wheat cultivation and the rapid diffusion of corn (introduced along with other new-world crops into the region during the mid-16th century). Corn would become the staple food of an impoverished and frequently malnourished peasantry. Rotation of grains with fallow and leguminous grasses gradually gave way to a soil depleting biennial wheat and corn rotation given the rapid expansion of population in the hinterland (Provincia di Venezia 1994a).

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[15] Despite the existence of public forests and the sovereignty of the Republic over private forests, competition for timber was intense as other cities required timber for their own needs and private owners also sought to profit from the forests. Furthermore competing interests within the Republic (e.g. navy, public works magistrate) attempted to procure greater quantities of wood for their own needs.

Overall, despite the great territorial restructuring and the expansion of cultivated areas, this era proved to be relatively stagnant in terms of agricultural and social development. The combination of poor organisation (owing to different ownership interests), repressive productive relations (the mezzadria), and agricultural practices which had not substantially changed from antiquity conspired to prevent the most rational and efficient use of agricultural resources and improvement in social and economic conditions (Provincia di Venezia 1994a).

5. Austrian and Post Unification Era

The 19th century ushered in profound political changes and technological developments, which laid the foundation for the large-scale land transformations of the 20th century. Politically, the invasion of Italy by French emperor Napoleon Bonaparte in 1797, and the subsequent armed conflict with the Austrian empire, which controlled the Lombardy region of Italy, put an inglorious end to Venetian domination of northeastern Italy. That same year the Republic voted to dissolve itself, and its former lands were divided with the Austrians retaining control of the *Friuli Venezia Giulia* portion of the Veneto (Present day Friuli Province). This arrangement lasted until 1814 with the fall of Napolean. After this, the Veneto and Lombardy regions were placed under the control of the Austrian Habsburg empire as decreed by the Congress of Vienna in 1815.

The fracturing of the old city state and provincial system by Napoleonic rule, and its attempt to introduce uniformities in law and civil equalities (including the abolition of feudalism which still remained in much of Italy), set into motion a movement of national unity. This eventually achieved the formation of the Italian State in 1861. The Veneto region was finally captured from the Austrian empire in 1866 (Gunn 1971; Provincia di Venezia 1983).

The political unity of Italy paved the way for the rapid expansion of the railway and road network, begun during the French and Austrian periods (Walker 1967). This expansion facilitated industrial, and especially agricultural development, which among other things was hampered from poor transportation links between producers and markets (Provincia di Venezia 1994a). A technological innovation of the era which held important significance to the region, was the development of the steam engine and mechanical pumps. This opened the door to large-scale reclamation of marshy coastal areas in the late 19th and early 20th centuries. Until then, reclamation only occurred in areas with sufficient slope for natural drainage (Fassetta 1977).

Economically, the 19th century represented a relatively static period for agriculture despite improved transportation networks, new technological developments such as chemical fertilisers and farm machinery, and expansion of irrigation and drainage schemes. This situation, again, could be blamed on disorganised and inefficient ownership structures and the enduring repressive productive and property relations (Provincia di Venezia 1994a). While large farms utilising salaried labour did exist, the vast majority of land was held by the nobility and small landowners who employed tenant farmers or the mezzadria. Thus after paying the required share of production to the owner, the peasant farmer, who still represented the primary means of agricultural production, would in most cases be guaranteed a bare subsistence level existence. As a result, he had no incentive to invest in productivity improvements, nor any surplus capital to invest in perhaps his own plot of land. [16]

The persistence of this type of social and economic organisation not only conspired to depress agricultural production and social development, it likely also served to maintain the *piantata* which has been called a by-product of the rural economy (Provincia di Venezia 1994a). From its Greek and Etruscan origins, the piantata reached its maximum diffusion during the 19th century to become the characteristic feature of the landscapes of Emilia-Romagna and Veneto regions (Sereni 1961; Tempesta 1989).

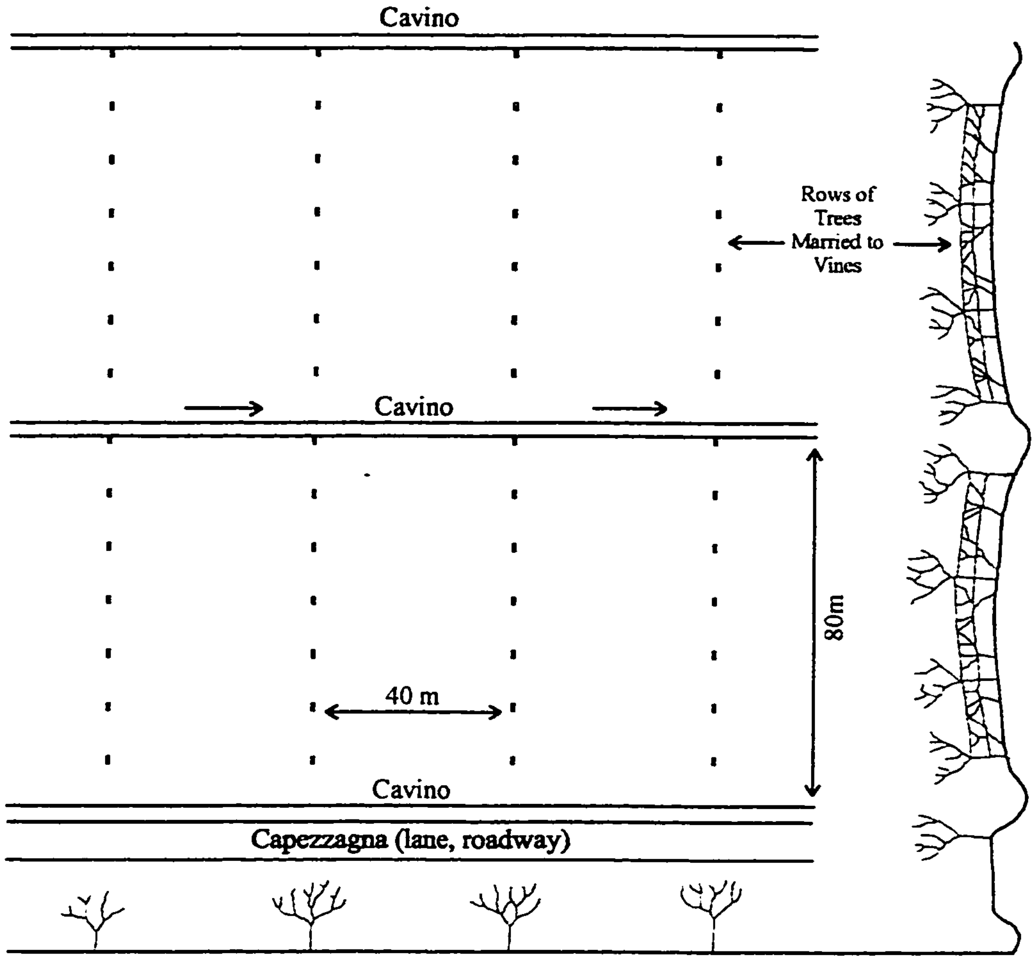
[16] It is important to mention that beyond the *mezzadria*, the most repressive and widespread of all relationships, owner-tenant arrangements varied widely and were entirely at the discretion (and goodwill) of the owner. The *mezzadri* were required to return one-half of all production including livestock, wine and grain. However, other more favourable (to the peasant farmer) arrangements existed such as those where only a portion of wine and grain were returned as rent, or cases where a monetary sum was paid based on the amount of land rented.

The typical landscape of the piantata was characterised by rectangular fields 25 to 50 metres wide with a length of roughly triple this distance, separated by 4-5 metre wide single or double rows of trees married with vines. The length was based on the distance oxen could plow before needing a rest. Denser hedgerows would mark property limits and line perimeter corridors such as roads, rivers and canals. In the lower Venetian plain, fields were more irregularly shaped and were normally intersected by drainage ditches *(cavini)*. This was due to more impermeable soils and gentler slope compared to the upper plain (Tempesta 1989). Most fields in the lower plain had a crown in the middle to facilitate drainage. Figure 3.6 provides an illustration of the piantata and a typical layout of a field in the lower Venetian Plain.

The endurance of the piantata could be attributed to the practical and productive functions it served in a region where agricultural practices underwent only gradual changes over almost three millennia. In addition to serving the time-honoured functions of lining ditches, delimiting the borders of fields, supplying grapes for wine-making, and providing raw materials needed for self-sufficiency (fuelwood, poles, fodder), the economic function of the piantata was expanded and incorporated into the 19th century rural economy. The gradual replacement of elm, willow, and hedge maple tree species with mulberry trees (for the practice of silkworm culture) expanded the productive function of the piantata. In most cases the tenant farmer was now expected to practice both viticulture and silkworm culture, and to include them as part of the rent owed to the owner.

From an ecological perspective, the piantata can perhaps be considered as representing a form of **equilibrium landscape**. This equilibrium had both cultural and ecological aspects. From a cultural perspective, the landscape of the piantata was a classic governed landscape. It was perpetuated because of its productive function in the subsistence agricultural economy. This economy was in turn driven by existing technological, economic and social conditions of the era. Furthermore, the cultural perpetuation of the piantata resulted in a form of vegetation equilibrium

Figure 3.6
Typical Layout of Piantata Veneta



Sources: Tempesta, 1989 (upper) and Sereni, 1961 (lower).

as hedgerows and rows of piantata represented the "natural" vegetation in the landscape.

The organisation and mapping expertise of the Austrian Empire provides us with the first accurate image of the landscapes of the Venetian Plain and Lower Piave. This is in the form of a 1:86,400 series of topographic maps compiled in 1833. A digitised enhancement of the landscapes of the lower Piave area is provided by Map 3.6. From the map it is apparent that the Lower Piave was still largely comprised of marshlands as it likely had been centuries. Land reclamation was restricted to areas adjacent to the Piave river where higher areas had been gradually converted first to pasture/meadow and then arable lands using the *colmata* or fluvial method or reclamation. Generally speaking, pasture immediately followed reclamation and preceded the conversion to cultivation. This was due to the fact that grazing and fodder activities were feasible on newly reclaimed land, or those on the margins of marshes, which still suffered from imperfect drainage. Gradually, newly reclaimed areas would be levelled and sloped for agriculture. Otherwise, the marshy areas remained sparsely populated and life revolved along fishing, hunting and cultivation of marginal lands.

The first attempts at manipulation of the low lying marsh areas in the 19th century were undertaken by *Consorzi Idraulici*[17] and focused on modifying drainage and constructing canals to facilitate drainage and mitigate flood risk. The invention of the steam engine spurred initiatives to reclaim larger portions of the low-lying marshes in order to gain more agricultural land. The first reclamation was largely the effort of individual owners with large holdings. However, the great expense and human effort required, as well as frequent miscalculation of necessary pumping capacity, doomed most of these projects to failure and bankruptcy was a common occurrence.

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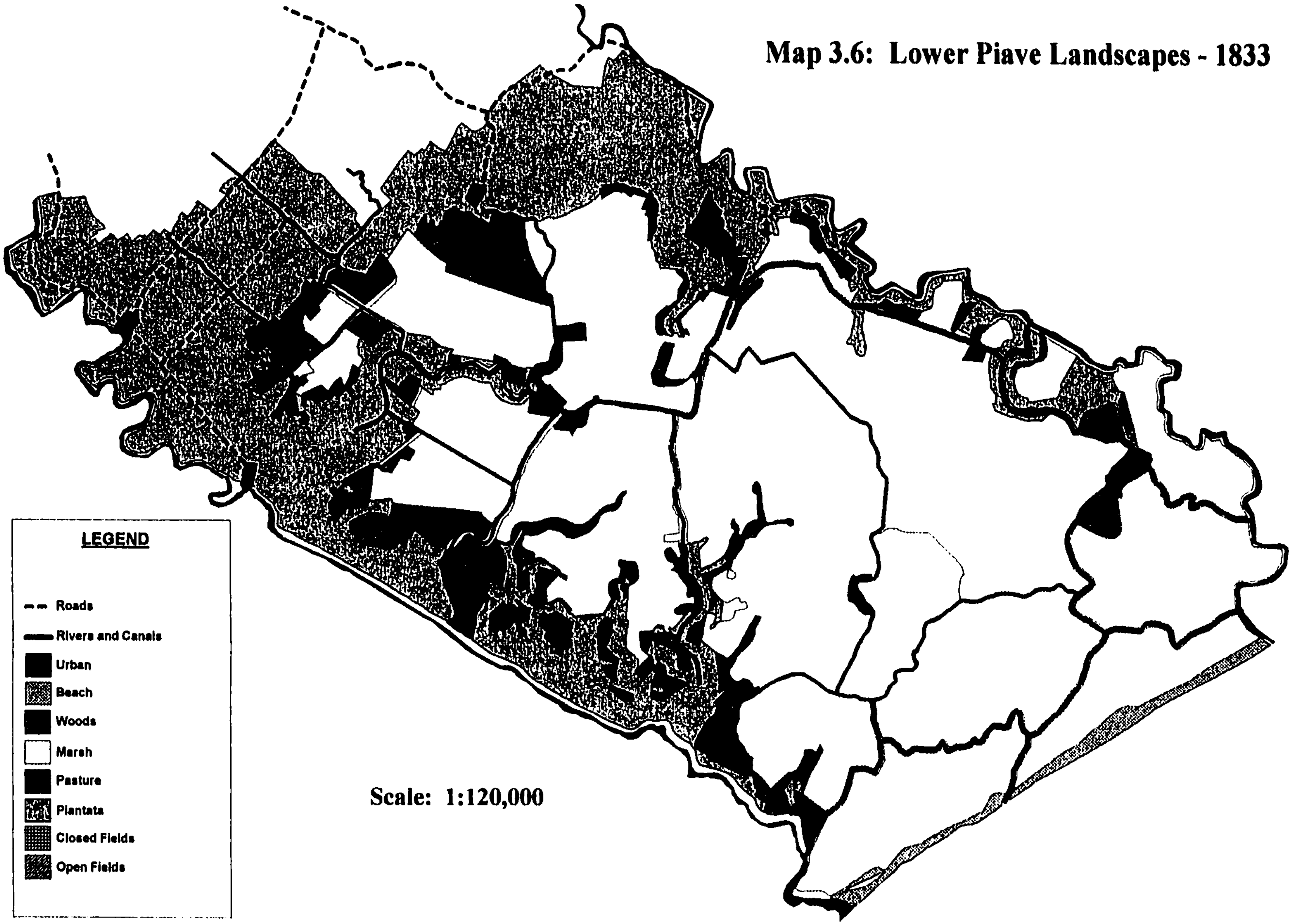
[17]These early *Consorzi Idraulici* were the precursers to the present day *Consorzi di Bonifica*, or land reclamation bureaus that undertook the large scale reclamation, and today manage and administer reclaimed lands. The Consorzi Idraulici (mandated by an 1865 public law) were quasi public autonomous bodies which operated under the direction of the federal government. Initially, they preoccupied themselves with works to improve drainage and mitigate flood risk, such as the construction of dikes, canals, ditches and re-excavation of existing canals. The Consorzi Idraulici would be composed of membership by individual land owners who would contribute funds toward improvements based on their holdings in a particular basin (Fassetta 1977).

Map 3.6: Lower Piave Landscapes - 1833



Source: Carta Topografica del Regno Lombardo Veneto (1833); 1:86,400

It was not until a series of federal laws passed in the late 19th century that land reclamation proceeded on a large scale in the Lower Piave area and coastal Italy as a whole. Beginning with the 1882 *Baccarini* Law, and followed with state law n.195 in 1900, the State government implemented mechanisms for public funding and coherent organisation of land reclamation under *Consorzi*. This after it recognised that the advantages brought by extensive land reclamation would not be realised under strictly private initiative. Initially, the state was interested in reclamation primarily as a means to battle the age-old curse of malaria. It later decided that reclamation for agriculture could represent an important contribution to the economic development of a country which was still mostly poor and underdeveloped (Fassetta 1977).

Following these developments, the 20th century brought two stages of sweeping landscape changes to the Lower Piave. During the first stage, corresponding roughly to the first half of the century, reclamation proceeded to transform virtually all low lying marshy areas into *highly governed* agricultural landscapes. These were often based on the traditional 19th century model of closed fields and piantata. The second stage of land transformation saw the alteration of traditional landscapes to meet the needs of modern agriculture. The nature of these transformations is examined in detail in Chapter 5. Also examined are the social, cultural, and economic factors, which spurred these transformations.

3.4 CONCLUSION

In summary, this Chapter has provided a geographical and historical introduction to the Venetian Plain and Lower Piave area. Through the landscape history, this chapter has provided important information concerning the nature of agricultural landscapes, landscape change and human governance of landscapes up to the 20th century. From a landscape governance perspective, a number of important conclusions arise that are relevant to the issue of biophysical landscape health. These are outlined and discussed at the conclusion of Chapter 5 when the entire history of land governance and landscape transformation related to the Lower Piave has been outlined.

Nonetheless, at this stage of historical landscape analysis it can be concluded that the Roman era holds the most significance from a landscape change and governance perspective. The Roman era ushered in widespread physical change in the Venetian Plain through settlement and the clearing of the forests for agriculture. From this point on, the Venetian landscape began its journey, albeit with interruption during the Medieval era, towards its present landscape form. In essence, landscape governance in this area was first initiated by the Romans. This precedent combined with cultural developments through 2000 years of human history, laid the foundation for the great landscape transformations of the 20th century.

Chapter 4: Methodology

This chapter describes the general research methodology employed for resolution of the central research goal\question stated in section 1.2 of Chapter 1. That is, **how can a concept of biophysical landscape health be interpreted for the Lower Piave highly governed landscape, and what are parameters for its measurement?** The methodology employed for resolution of the research problem closely corresponds to the four objectives noted in section 1.2. To these, one would also add the final task of developing an interpretation of landscape health based on the integration of findings from these four stages. In total, there are six stages to the process of interpreting landscape health. These include:

1) Review of the conceptual basis of "health" as it relates to landscapes and highly governed landscapes in particular;

2) Investigation of the historical and cultural context of landscape governance in the Lower Piave study area and surrounding Venetian Plain;

3) Investigation and illustration of 20th century landscape transformations;

4) Analysis and assessment of critical landscape elements in the Lower Piave during both the post reclamation " pre-modern era", and the "modern era";

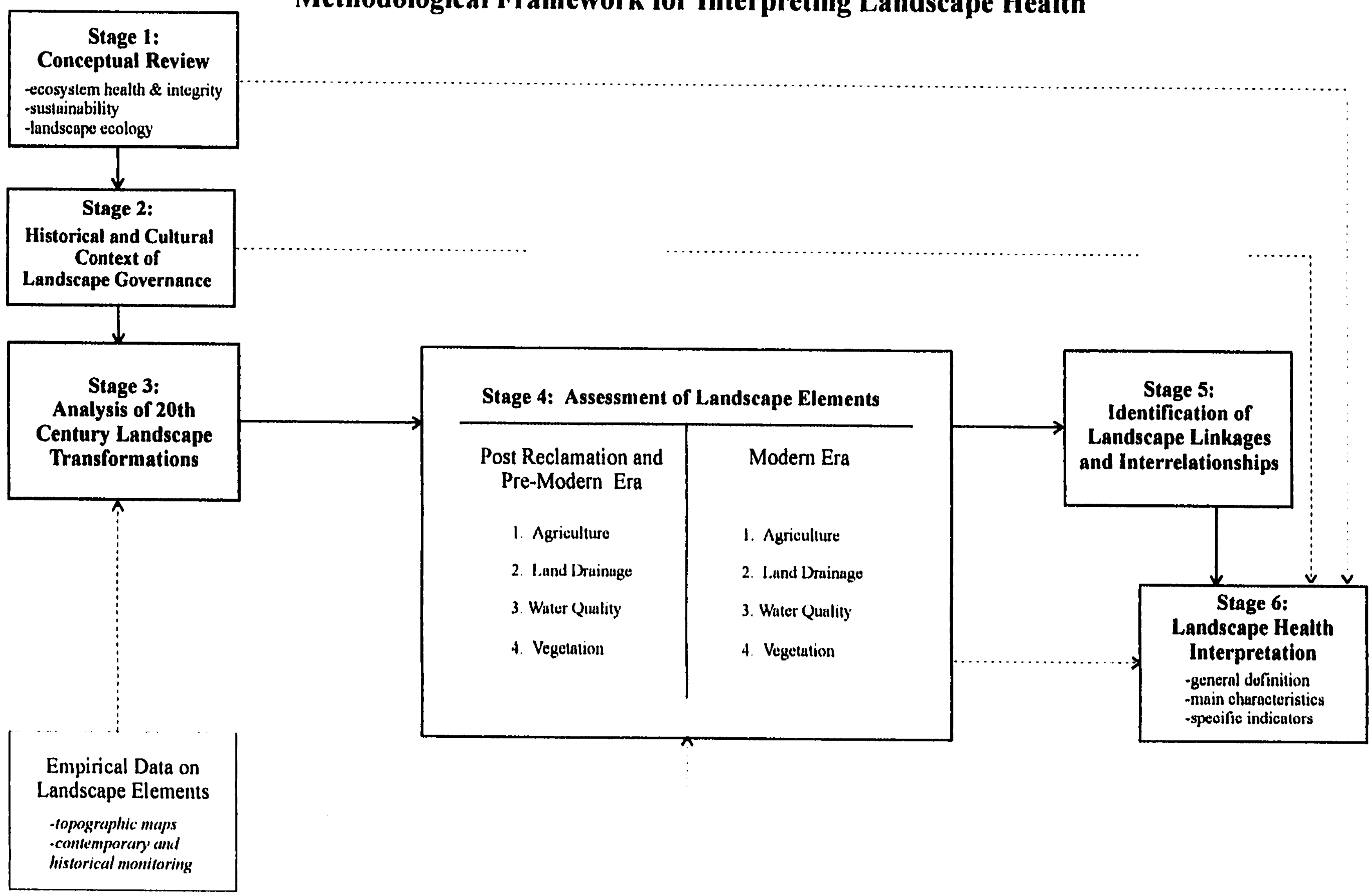
5) Identification of environmental and cultural linkages and interrelationships in the landscape;

6) Interpretation of landscape health based on the integration of relevant conceptual, cultural, and landscape ecological information garnered from the previous five stages of analysis.

A diagrammatic representation of the entire methodological process is depicted in Figure 4.1. The solid lines represent the sequence of investigation and analysis from stages one to five, which is designed to lead to the completion of the final stage in Chapter 7. The broken lines leading to Stage 6 indicate that interpreting landscape health is a process of integrating findings from conceptual review, historical and cultural inquiry, and landscape transformation analysis. At this point in the study, stages 2 and 3 have already been completed in Chapters 2 and 3

Figure 4.1

Methodological Framework for Interpreting Landscape Health



respectively. This chapter will therefore focus on the remaining four stages of the methodology.

Prior to discussion of the remaining stages, it is worth mentioning that the results presented in this dissertation are the product of 5 years of preparation, fieldwork, analysis, writing and revision. The first two years were spent in Ph.D. course work, preliminary conceptual review, and proposal formulation. This was followed by two periods of fieldwork in northeastern Italy. The months of October and November 1995 was spent travelling through the northeastern Italian coastal zone and conducting preliminary investigations regarding potential information sources and available databases related to issues of health and reclaimed landscapes. The home base for this investigation was the **Department of Geography** at the **University of Padua**. The Department provided a place to work and access to library and department resources. During this period, considerable time was spent investigating library resources, establishing contacts, and having preliminary discussions with researchers, academics and government agencies regarding accessible databases and information sources. This fieldwork was followed by a refinement of research goals and methods based on available data and information.

A more intensive period fieldwork occurred from late May 1996 to early October 1996. During this time, topographic maps, historical documents, agricultural census data, biophysical studies and other documents pertinent to the goals and objectives of the research were acquired. Time was also spent having discussions with knowledgeable individuals regarding issues related to research and additional sources of information.

The conclusion of fieldwork was followed by an intense 15 month period of data preparation (digitisation of topographic maps), analysis, and writing to produce this completed study. A preliminary dissertation draft, prepared by January 1998, was followed by a revised version approved for a defence date in late June 1998.

This chapter also includes comments concerning constraints and operational limitations associated with various aspects of research. This project faced significant limitations, which affected research results. From a data and information perspective, there are difficulties associated with conducting research in a different cultural and intellectual setting from where a research problem is formulated. Study goals, objectives, and analysis ultimately have to be tailored to existing information and data available in the study area. Therefore the depth and rigour of the analytical part of the dissertation is constrained by available information and databases.

Furthermore, there are time and resource constraints associated with any research project. These are magnified when working in a distant study area, as this research was conducted on a very tight financial budget. There are also constraints associated with academic time limits. Thus judgements had to be made along the course of research as to if, and when, enough data was collected to begin analysis. Information and technical constraints associated with this research are mentioned along each stage of the research methodology.

Stage 3: Investigation of 20th century landscape transformations

The landscape history in Chapter 3 indicated how the Venetian Plain became a "governed" landscape over the course of 2000 years until the end of the 19th century. This stage takes a close look at the 20th century when the Lower Piave became a highly governed landscape. This stage is contained in Chapter 5 and has two specific objectives. One is to trace the process of how the Lower Piave area became a highly governed landscape during the 20th century, including the driving social, cultural and economic factors. The second objective is to visually and empirically illustrate two phases of 20th century landscape transformations. The two phases include initial land reclamation to create the highly governed landscape, followed by the transformation of landscapes with the post World War II modernisation of agriculture. The second phase of land transformation marks the division between the "pre-modern", and "modern" eras. This distinction is pertinent to the analysis in Stage 4, where the state and condition of critical landscape elements is compared between these two eras.

In addition to illustrating transformation to a highly governed landscape and subsequent change, the purpose of this stage is to illustrate the nature and spatial extent of land cover types and cultivation systems at various points during the 20th century. This information is vital to the study for a number of reasons. First, **the post-reclamation highly governed landscape represents the starting point for the comparisons undertaken in stage 4** (found in Chapter 6). For research purposes, the "pre-modern" era in the Lower Piave effectively begins from the time of land reclamation. Therefore landscape trends, and their relation to landscape health are of particular interest from this period onward as this enquiry focuses on highly governed landscapes and not the preceding marsh landscapes.

Moreover, an empirical analysis of landscapes is also restricted to the 20th century because information to reconstruct land transformation is readily available in the form of topographic maps. Prior to this era, this detailed information is lacking and description of landscape change has relied upon descriptive historical accounts and more recent (and larger scale) topographic maps dating from Austrian control of the region.

The nature and spatial extent of land cover types and cultivation systems also has important implications concerning landscape health. In Chapter 2, certain landscape patterns were identified as being more amenable to biological diversity and overall integrity from a biophysical standpoint. Therefore, the examination of landscape states at various points in time following reclamation provides important indications as to the "health" of landscapes based on standards of diversity and integrity. This information is used when conceptualising landscape health.

In Chapter 5, a series of maps and simple area figures have been produced to illustrate the evolution of Lower Piave land cover characteristics and cultivation systems over the past century. These have been reconstructed using the digitisation of land cover information from 1:25,000 series topographic maps produced by the *Istituto Geografico Militare*, or IGM (Italian Military Geographic Institute), and the 1:10,000 series technical maps produced by the Veneto Region (*Carta Tecnica Regionale*). The IGM is the chief mapping agency of the Italian State, and has produced a number of editions of 1:25,000 series topographic maps dating back to 1891. The most recent edition of the 1:25,000 maps dates only to the 1960's; hence the 1:10,000 maps produced by the Veneto region are used to provide the most recent version of land cover.

The topographic maps are the primary data sources for this analysis because they are one of few databases available which provide consistent environmental and landscape information over an extended period of time. Map editions published for the years 1908-10, 1960-68 and 1990 (1:10,000) have been used to detail land transformation. The information on 1:10,000 maps is the same as the 1:25,000 maps, so consistency of information is preserved between the two series of maps. The 1990 map edition is based on air photos taken during 1980's flights, while the 1960-68 maps are updated versions of the 1954 flights by the United States military (the first series of air photos taken in Italy).

The 1908-10, 1960-68 and 1990 years have been chosen because they correspond to important benchmarks. The 1908-10 series represents the first year that a complete series of maps is available to the public.[1] The 1960-68 series is not only the last complete series for the 1:25,000 maps, but also shows landscapes at a critical stage. While some areas still reflect traditional cultivation systems, others are beginning to show radical land transformation caused by the wholesale mechanisation and modernisation of agriculture. Finally, the 1990 series is the last complete series of topographic maps available, and illustrates the modern agricultural landscape.

Landscape transformation has been recorded by manually digitising **land cover**

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[1]While some maps for the 1891-92 series were available at the Department of Geography at the University of Padua, missing ones could not be ordered from the IGM as technically this series is not available for public consumption.

characteristics in the study area. Land cover characteristics are standard land classifications designated on each topographic map edition, and include:

- urban concentrations *(zone costruite)*
- marshes *(palude)*
- woods *(boschi)*
- dune/beach areas *(dune ed coste)*
- pasture or uncultivated fields *(prati e pascoli)*
- agricultural/cultivated lands

The category of "agricultural/cultivated lands" is further subdivided into different **cultivation systems,** which at one time or another were (are) found in the Lower Piave area and surrounding Venetian plain. These include:

- fields with rows of vines married with trees *(piantata)*
- closed fields bordered by hedgerows and trees *(campi chiusi)*
- open fields with absence of hedgerows and trees *(campi estesi ed aperti)*

The subdivision of agricultural lands into specific cultivation systems is needed to capture important differences in agricultural landscapes, and their variability over time. Within both the Venetian Plain and Lower Piave, different cultivation/field systems have existed within the context of agriculture over the time. The restriction of cultivated lands to only a single category of "cultivation" is insufficient for the purposes of this research, as there are landscape health implications associated with specific cultivation systems. Cultivation systems must therefore be identified and differentiated.

As for the categories of cultivation systems, the ***piantata*** has already been extensively described in Chapter 3. **Closed fields** refer to areas of cultivation frequently intersected or divided by hedgerows. The criterion for the classification of "closed fields" is taken from Tempesta's (1989) work on traditional landscapes of the Veneto. Tempesta defines them as cultivated fields enclosed by hedgerow structures to a maximum span of 200 by 200 metres. The classification of **open fields** stems from the criterion used to define closed fields. Open fields are designated by cultivated areas spanning distances of greater than 200 metres without any form of hedgerow.

These land cover and cultivation designations also reflect cultural landscape classifications used in the agricultural and landscape literature. References to these classifications can be found in Provincia di Venezia (1994a), Maffioli (1990), Tempesta (1989), and Sereni (1961). Many of these categories, including the *piantata*, are also designated by agricultural censuses available at various points in time (Sormani-Moretti 1880-1; Istituto Centrale di Statistica del Regno d'Italia 1930; ISTAT 1972a, 1985 & 1991a).

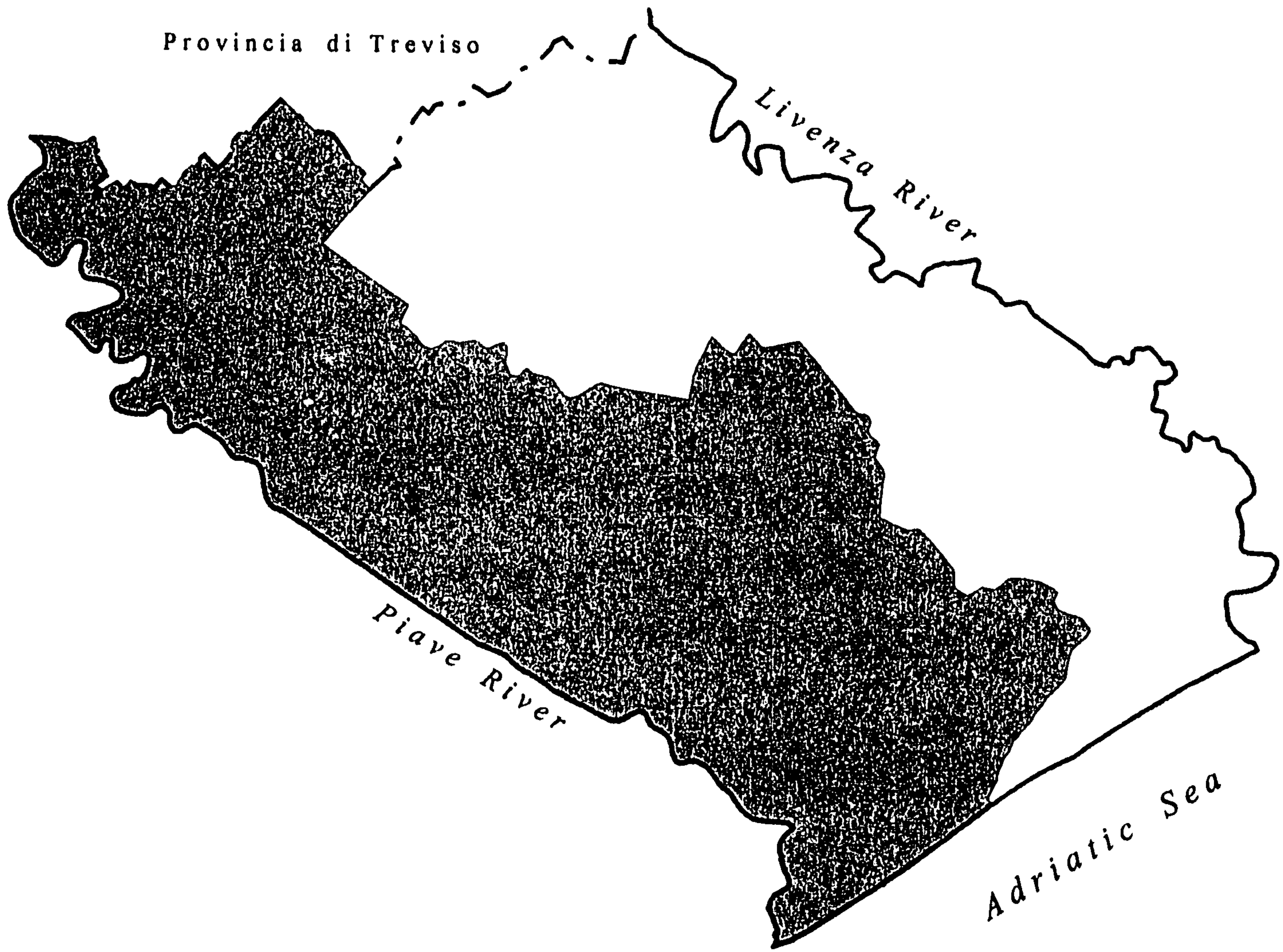
The geographic area digitised is illustrated in Map 4.1 and represents only a portion of the Lower Piave area. A smaller area was digistised because of the labourious and time consuming nature of digitising land cover features. The production of Maps 3.6, 5.1, 5.2 and 5.3 required three months of full time work by the author, combined with the services of a teaching assistant provided by the thesis advisor for one term (130 hours). Thus, the sheer amount of time required to manually digitise information is a constraining factor when selecting the temporal and spatial boundaries of landscape transformation analysis.

The graphic illustration of 20th century land transformation is followed by a more empirical analysis of landscape patterns in the Lower Piave. This is undertaken through the application of some of the landscape indices discussed in section 2.3. Specifically, **diversity** and **dominance** indices are calculated and interpreted for the three periods under investigation. These measures are intended to empirically illustrate landscape heterogeneity. Their application and relevance to landscape health is discussed in Chapter 5. This information is used in Chapter 7 to draw conclusions regarding landscape patterns and thresholds (values) which are more conducive to the health of these highly governed landscapes.

Stage 4: Analysis and assessment of critical landscape elements

This stage involves the analysis and assessment of key landscape elements in the Lower Piave using available data. This analysis is contained in Chapter 6 and consists of the examination

Map 4.1: Comparison of Digitised Area with Entire Lower Piave Study Area



of **agriculture, surface drainage, water quality, and vegetation**. During the course of research, these elements have been identified as the most significant landscape variables in the highly governed landscape.

Surface water drainage is a crucial element given the physiography of northeastern Italian reclaimed areas, and the geography of the Venetian Plain.. The Venetian Plain is generally a water rich area with a large number of rivers flowing from alpine areas into the Adriatic Sea. A dense grid of drainage ditches and collector canals drains reclaimed coastal areas, including the Lower Piave. The efficient drainage of these areas is the most significant aspect of land governance given a large portion of these areas is at, or below sea level. As noted in Chapter 3, water management has always been a key aspect of land governance in the Venetian Plain. Both drainage and water quality are also closely tied to vegetation and agriculture respectively.

From a cultural standpoint, agriculture represents the most important human activity in the Lower Piave. Its evolution has had a direct impact on land drainage as will be discussed in Chapter 6. Current agricultural practices also have negative impacts on water quality, which is a significant environmental concern in the region. Finally, vegetation is a key landscape element given how closely interconnected it is to other landscape elements. It has also always been an important component of traditional Venetian agricultural landscapes as noted in Chapter 3.

The objective of this stage is to examine and compare the state and condition of these elements during both the modern and pre-modern era. The purpose of this stage is threefold. One is to determine the state or condition of these elements from a health perspective and to identify relevant health issues in the landscape. Another purpose is to determine interrelationships between key elements in the landscape. The final purpose is to identify potential indicators/characteristics of biophysical landscape health based on the condition of these elements during the two different eras. In essence, the purpose of this analysis is to shed light on the workings of the highly governed landscape, which is a prerequisite to understanding landscape health.

The analysis of each key landscape element emphasises its evolution over the last century or so, and is based on a comparison between its condition in the **pre-modern** and **modern** eras. As stated previously, the modern era corresponds to the post W.W.II period and the industrialisation of Italy. The pre-modern era is defined as that existing prior to this transformation, but following reclamation in the first few years of the 20th century. The established post-reclamation agricultural landscape had many similar characteristics to traditional Venetian landscapes.

Data collected during field research is analysed for each era to obtain a representation of conditions and trends. It should be noted that this analysis is constrained by data limitations. Visible gaps in each segment of analysis are attributable to the paucity of data and studies on the condition of these elements, especially with respect to historical data. The one exception is agriculture, which benefits from the existence of census data dating back to the latter part of the 19th century. During fieldwork, every effort was made to obtain studies on the state of biophysical landscape elements and the current conduct of agriculture. However, environmental monitoring in Italy is piecemeal and data tends to be aggregated at the regional level. One exception is water quality, which is well monitored, but nonetheless tends to focus on larger watercourses at the regional level (Regione del Veneto 1993). Thus, the analysis relies on a collection of studies, reports, articles and documents relevant to the goals of this research and specific to the study area.

The evaluation of agriculture focuses on **sustainability** and **agroecosystem health** principles outlined in Table 2.6. Sustainability is the assessment vehicle because it appears best oriented toward the evaluation of sectoral activities. It should be emphasised that the evaluation of agricultural sustainability focuses on biophysical landscape principles and farming system characteristics only. Social and economic aspects of sustainability are omitted because their proper consideration requires further investigation of considerable magnitude given there are no available studies on this issue (especially regarding the issues of historical trends in sustainability). Social and economic issues have also been omitted for general reasons stated in Chapter 1.

The evaluation of agriculture is largely a process of deduction based on available empirical and historical evidence regarding the key principles considered from Table 2.6. As to comparing the sustainability of agriculture between the two eras, the most important issue is how farming systems and agricultural practices conform to these sustainability principles in both eras. A process of deduction is used because no specific studies were found which provided any assessment or conclusions regarding the state of agricultural sustainability in terms of land use and agricultural practices.

The evaluation of water quality focuses on "**distress**". This is a common approach to assessing water quality and has been used by the studies consulted for the water quality analysis. These studies have utilised the classification systems and indices illustrated in Tables 2.1 and 2.2. Acceptable thresholds, as defined by EU and Italian legislation, are also used to assess water quality distress related to the runoff and discharge of nutrients. Again, assessment of water quality trends is restricted by both the lack of historical monitoring of water quality and limited contemporary monitoring in this area. Therefore, conclusions regarding historical trends have been drawn using available written historical evidence, and the analysis of current distress focuses on areas that have been monitored. A comprehensive basin wide analysis of water quality is impossible due to data restrictions.

The analysis of drainage focuses on pumping capacity needed to drain the basins in the Lower Piave. This focus is taken because the best available data to assess drainage is that of pumping capacity upgrades over time and associated runoff coefficients (udometric coefficients). Data on pumping capacity is available since the onset of reclamation. The evaluation of drainage conditions is based on the need for stable water levels in the basin in order to minimise economic and social costs of reclamation and low level flood risk.

The analysis of vegetation has a landscape ecological emphasis. The methodology is outlined in detail in section 6.5. In brief, it consists of examining vegetation structural change between two periods where air photos are available (1954 and 1983), and assessing the significance of change. The analysis of vegetation structural change is accomplished through four steps, including:

1) Selection of two land cells within the Lower Piave;
2) Identification/recording of hedgerow corridors in each cell for both 1954 and 1983;
3) Graphical presentation and comparison of structural change between 1954 and 1983;
4) Interpretation of structural change in terms of vegetation composition.

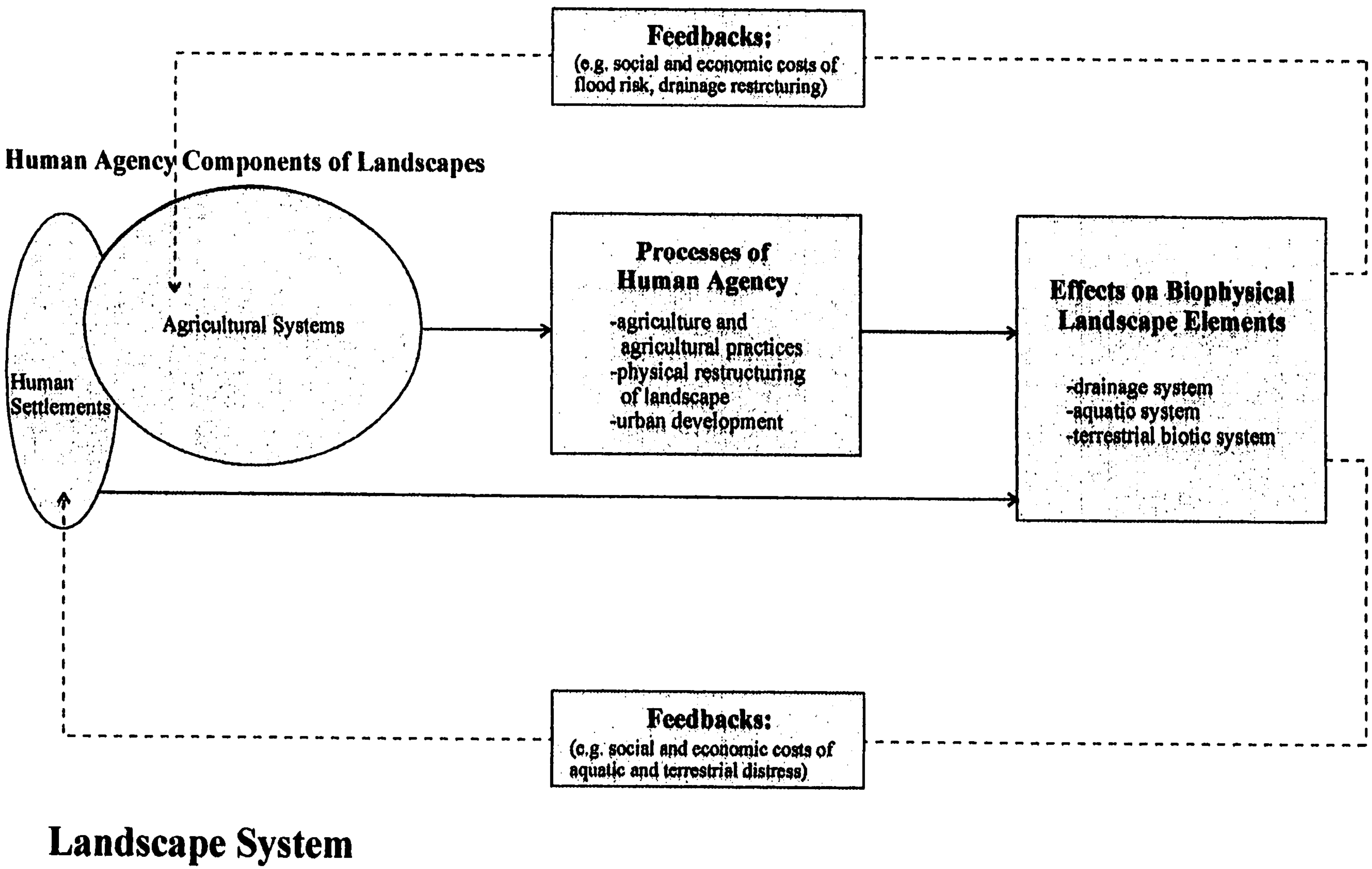
The significance of vegetation change is assessed using the standard of the **productive and ecological functions provided by these structures**. The productive functions of hedgerows was illustrated in Chapter 3, while some of the ecological functions have been identified in Chapter 2. More detailed discussion of additional ecological functions is provided during this analysis. Information from the vegetation analysis, and the significance of change, is applied to the discussion of landscape health in Chapter 7.

Stage 5: Identification of landscape linkages and interrelationships

This stage consists of establishing and identifying the linkages and interrelationships in the highly governed landscape. The information for this stage has been garnered from the landscape analysis of the previous stage. All key landscape elements examined in Chapter 6 are considered with the addition of human settlement. The basic framework for this stage is illustrated in Figure 4.2. A more detailed version of this framework which fully illustrates landscape linkages is provided by Figure 7.1 in Chapter 7.

The framework is designed to portray the landscape as a system consisting of interacting elements and processes. On Figure 4.2, there are three main ambient factors identified as best

Figure 4.2: Framework for Depicting Landscape Interrelationships and Linkages



representing the ecology of the landscape in terms of the interplay between cultural and biophysical elements. They include:

- Human agency components (principle human activities present with the capacity to alter landscapes);
- Processes of human agency (key actions associated with these activities);
- Biophysical landscape elements (the main biophysical elements from Stage 4).

The framework of Figure 4.2 depicts a basic chain of relationships in the landscape. Human agency components include human settlement and agricultural systems. Associated with these human agency components are human agency processes such as the expansion and improvement of urban settlements, and activities associated with agriculture, such as alteration of agricultural landscapes and application of agricultural inputs. These processes of human agency are in turn linked to biophysical landscape elements. In contemporary Lower Piave landscapes, processes of human agency are shown to have mostly negative impacts on biophysical landscape elements. While his does not always have to be the case, **the framework of Figure 4.2 is designed to illustrate the negative impacts of human agency processes.**

The cycle is completed by the existence of feedbacks felt by humans in their settlements and farms. In the more detailed representation of linkages in Chapter 7, most of the feedbacks cited are negative (in the sense of creating stresses). However, this is not always the rule as feedbacks may be positive (as in the landscape continuing to provide essential ecological functions to humans). The information garnered from this stage assists with developing a landscape health concept for highly governed landscapes.

Stage 6: Development of a biophysical landscape health interpretation

Stage 6 consists of the integration of information from the previous five steps to develop an interpretation of biophysical landscape health for the highly governed landscapes of the Lower Piave. **The landscape health concept is illustrated through a broad definition followed by a**

series of key characteristics of landscape health. For each characteristic, parameters and some thresholds are proposed for measuring and quantifying these characteristics.

The process of defining landscape health is best described by a series of multiple questions relating back to previous research stages. Through referral to previous stages, the response to these questions constitutes the analytical and thought process behind the interpretation of landscape health. The first set of questions relates to the conceptual review undertaken in Chapter 2:

*1) What properties and characteristics of **ecosystem health** are relevant to northeastern Veneto landscapes, and measurement/assessment of their health?*

*2) What **ecological integrity** principles are relevant to the health of governed and highly governed landscapes?*

*3) What aspects of **sustainability** are relevant and measurable in the case of northeastern Veneto agricultural landscapes?*

*4) Which landscape structural features, as examined in the **landscape ecology** review, best promote health in governed and highly governed landscapes?*

The second set of questions relates to cultural and historical factors that have been examined in Chapter 3 (and which are summarised at the end of Chapter 5):

1) What are key historical findings regarding Venetian landscapes in relation to health?

2) What are key cultural findings regarding Venetian landscapes and governance in relation to health?

The third set of questions is derived primarily from the landscape study in Chapter 6. One question has already been answered with the decision to select four key landscape elements for analysis:

1) What are the most important cultural and biophysical elements in the landscape?

2) What are the most important landscape interrelationships and linkages that bear on the health of landscapes?

In summary, the general definition of biophysical landscape health and its specific characteristics are moulded through consideration of these questions. Specific characteristics of landscape health also include some health properties defined by individual fields such as ecosystem health. The parameters for measuring and quantifying these characteristics of health are derived from four different questions:

1) *How are relevant properties of ecosystem health (to landscape health) measured and assessed?*

2) *How are relevant properties of ecological integrity measured and assessed?*

3) *How are relevant aspects of sustainability measured and assessed?*

4) *How are relevant landscape structural properties measured?*

These questions are resolved primarily by examining precedents established in the literature, but are always considered in relation to the context of highly governed landscapes, the biophysical characteristics of the Lower Piave, and findings from the analysis of Chapters 5 and 6. The conclusion of Chapter 7 includes a table summarising the measurability of each landscape health characteristic. Also included at the end of Chapter 7 is a discussion of landscape health in relation to the theoretical and conceptual material reviewed in Chapter 2, and the relative contribution of each field/discipline to landscape health.

Chapter 5: 20th Century Landscape Transformations

5.1 INTRODUCTION

The 20th century witnessed two stages of sweeping landscape changes in the Lower Piave. During the first few decades of the century, reclamation proceeded to transform virtually all low lying marshy areas into highly governed agricultural landscapes which were often modelled after traditional Venetian landscapes. The second stage of land transformation saw the alteration of these landscapes to meet the needs of modern agriculture. This chapter examines the 20th century in detail as it initiated the era of the highly governed landscape. It is also the landscape state on which the rest of this dissertation and formulation of landscape health is based on.

Section 5.2 illustrates the two phases of 20th century landscape transformations through a series of digitised maps. This is followed by discussion of the social, cultural and economic forces, which induced these transformations. Section 5.3 consists of a more quantitative analysis of landscape transformation through the application of **diversity** and **dominance** indices. Section 5.4 closes the chapter by outlining a series of conclusions, and corresponding discussion, on landscape transformation and human governance. These conclusions are drawn from the analysis of over 2000 years of human history in the region, and are considered to be fundamental contextual considerations for formulating an appropriate landscape health concept. At the end of the chapter, the reader should be familiar with the transformation of Lower Piave landscapes, their present physical form, and the historical and cultural context of land governance in the Lower Piave and surrounding area.

5.2 LANDSCAPE TRANSFORMATIONS AND DRIVING FACTORS

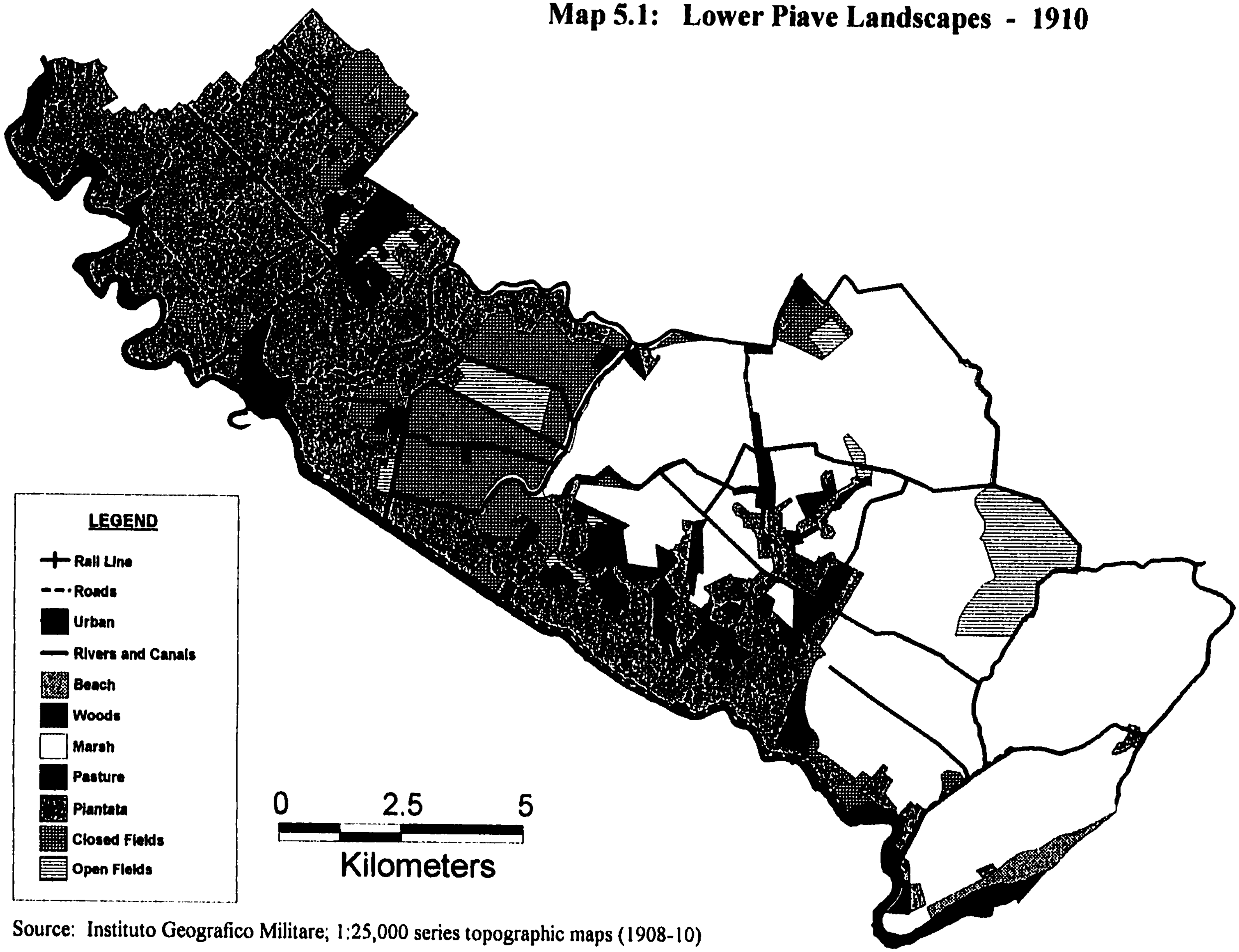
20th century land reclamation was the crucial era of landscape change as humans transformed marshlands to create a completely new form of highly governed landscape. This was also typical of reclaimed areas throughout Italy. The second phase of transformation saw the simplification of agricultural landscapes. This arose out of the collective actions of individual farmers responding to the new social and economic conditions created by the industrialisation and modernisation of the country after World War II. Later stages of landscape change were for the most part typical of the entire northeastern Veneto. Maps 5.1, 5.2 and 5.3 on the following pages depict landscape conditions at various points during this century, and also illustrate the phases of land transformation.

1. First Phase of Landscape Transformation

Starting from the turn of the century, large areas of marsh still existed in the Lower Piave with traditional cultivation (piantata) and pastureland existing in older landscapes, including those reclaimed by *colmata* methods. Older agricultural landscapes were found primarily adjacent to the Piave river and the *terraferma* portion of the Lower Piave whose limits extended roughly to the path of the Trieste - Mestre/Venice railway line (constructed in the late 19th century). Prior to mechanisation, reclamation was feasible, and undertaken, only where natural drainage permitted. Marshes remained where elevations tended to be lowest such as toward the coast and a large depression that occupied most of the area between the Piave and Livenza rivers (Map 3.6).

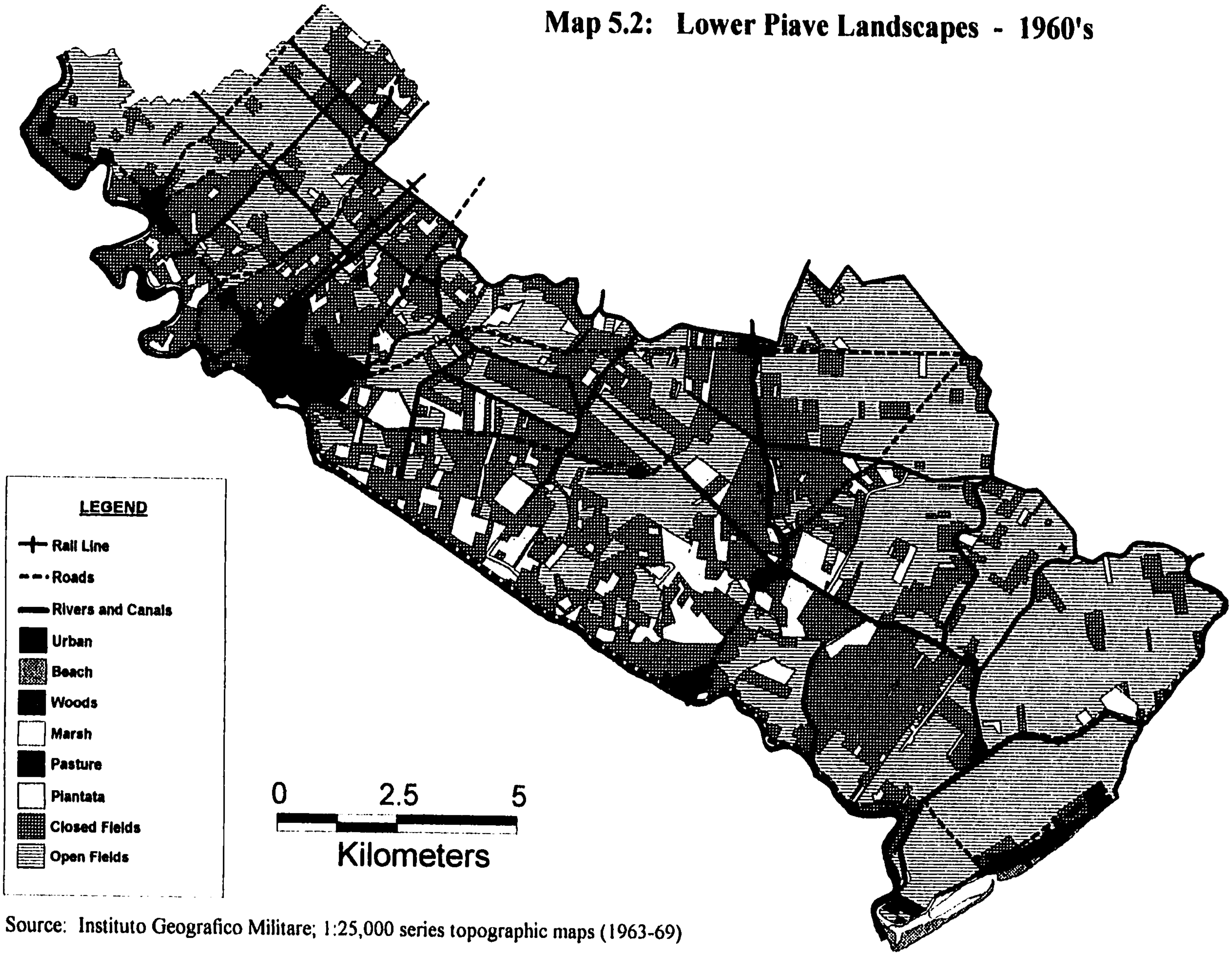
The snapshot of landscapes provided by Maps 5.1 and 5.2 illustrates the first phase of transformation. Map 5.1 shows a landscape that has changed little from the previous landscape snapshot provided by Map 3.6. The main changes between 1833 and 1910 were the conversion of some marshy areas to pasture/meadows and closed fields where natural drainage permitted. Pasture was often a typical land use after reclamation given a few years were usually required

Map 5.1: Lower Piave Landscapes - 1910



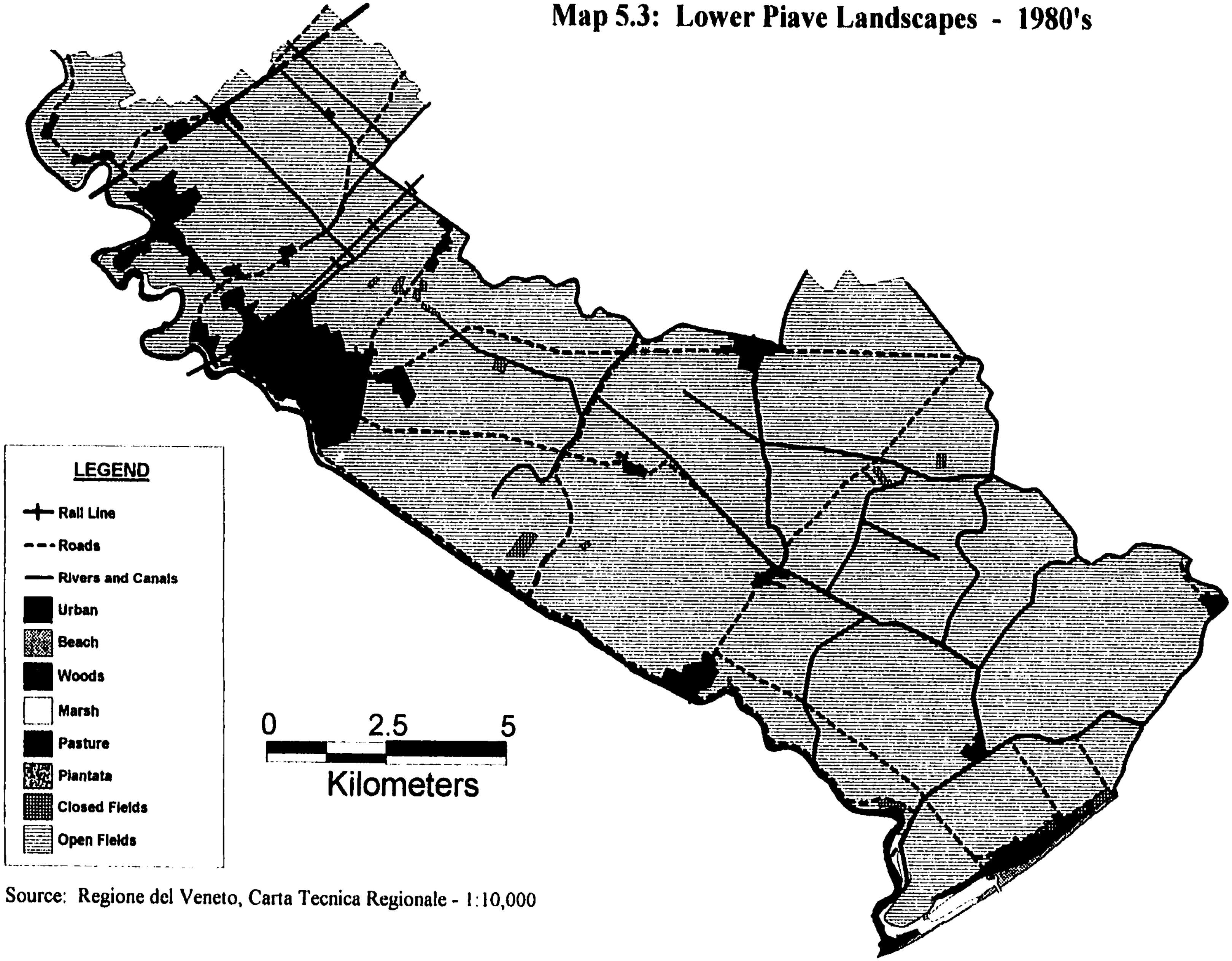
Source: Instituto Geografico Militare; 1:25,000 series topographic maps (1908-10)

Map 5.2: Lower Piave Landscapes - 1960's



Source: Instituto Geografico Militare; 1:25,000 series topographic maps (1963-69)

Map 5.3: Lower Piave Landscapes - 1980's



Source: Regione del Veneto, Carta Tecnica Regionale - 1:10,000 to level newly reclaimed land and correct imperfect drainage for crop growing. However, the majority of land area is still covered by marshes, especially towards the southeast.

By the 1960's, land reclamation in the Lower Piave has been complete for at least a couple of decades (Fassetta 1977), and a complex drainage and pumping network has been put in place. Within the span of about 40 years, a predominantly "natural" landscape has been transformed into a *highly governed landscape*. Map 5.2 also provides important indications as to the nature of post-reclamation landscapes prior to the second phase of transformation. At this time, there existed considerable areas of closed fields and piantata. Table 6.4 in Chapter 6 also confirms the existence of piantata on newly reclaimed lands. These cultivation systems were imposed on large areas because of the needs of subsistence agriculture, which was still prominent during the first half of the century. The nature of post-reclamation landscapes is also illustrated by land use statistics provided and discussed in section 6.2 of Chapter 6.

While reclamation produced sweeping landscape change during the first few decades of the century, it was in fact an uneven and difficult process. The process was also deeply tied to economic, technological, social and political conditions of the era. Consideration of these factors is essential for understanding land reclamation and landscape change. Land reclamation also represented an enormous and impressive engineering feat that overcame numerous practical and economic difficulties.

In practical terms, reclaiming marshland involved the construction of a complex network of drainage ditches, collector canals, dikes, pumping stations, roads and bridges. This proved to be a backbreaking task as it relied largely upon human and animal labour. Furthermore, reclamation was plagued with technical difficulties as common errors in initial calculations regarding drainage and pumping capacity resulted in frequent inundation during periods of heavy rains. This necessitated further improvements and modifications to drainage and pumping equipment. The latter was gradually improved with the development of the diesel engine, and later, hydroelectricity in the Italian Alps.

Economically, reclamation was an expensive proposition which created conflicts between the parties involved (the state, provinces, municipalities, and individual landowners). Reclamation required a massive investment of capital and its feasibility ultimately depended on subsidies (grants and loans) from various levels of government. Despite these subsidies, the landowner was still responsible for 50 percent of the cost, which usually necessitated a heavy debt load. The resulting precarious financial situation faced by most landowners led to constant calls for more government subsidies in order to guarantee an adequate return on investment (Fassetta 1977).

Practical and economic difficulties were compounded by the destruction from two world wars. During World War I, fighting with the Austrians reached the Lower Piave and resulted in considerable damage to infrastructure. Consequently much of the land reverted to marsh until infrastructure was rebuilt near the end of 1919. A similar upheaval occurred during World War II when reclamation of most of the Lower Piave had been completed. Infrastructure was immediately repaired after the war (1945-47). By the 1960's reclamation was completed on the few remaining marshy areas (Fassetta 1977). The impetus and will to overcome all the inherent difficulties associated with reclamation can be attributed to the prevailing political culture and social conditions of the era.

The combat of malaria was the primary motivating force for the 1882 and 1900 laws which spurred widespread land reclamation. Malaria had plagued coastal populations since time immemorial and had served to make the coastal marsh areas generally inhospitable to settlement. The city of Venice was the notable exception as the tidal actions of the Adriatic prevented the formation of stagnant waters favoured by malaria spreading mosquitoes.

Moreover, there were other dimensions associated with reclamation including the need to expand production in agriculture and the need to solve social problems plaguing the country. In terms of government policy, emphasis gradually shifted to these latter two dimensions. From an agricultural perspective, reclamation was seen as an opportunity to expand agricultural land to meet rising food requirements. It was also seen as a way to help modernise agriculture and alleviate economic "backwardness" by establishing new production systems and methods.

Socially, reclamation was seen as an opportunity to ease urban social conflicts caused by the migration of landless peasants to urban areas. This was spurred by the increasing economic rationalisation of agriculture and the usual miserable economic and social conditions faced by the rural peasantry. However, the equally unfavourable conditions faced by the new urban peasantry created a climate of civil unrest and strikes. The government therefore viewed the opening up and distribution of new lands as a means to diffuse the potential for social unrest, and rise of socialism, in both urban and rural areas.

The evolution from an initial hygienic emphasis to modernisation and social objectives was cemented with the 1928 *Bonifica Integrale* law passed by the Fascist government of Benito Mussolini (Zanetto *et al.* 1996). The 1928 law was aimed at:

1) Improving health conditions;
2) Promoting the setting up of new production activities;
3) Re-populating and building new homes in countryside areas; and,
4) Transforming landed property in order to reduce social conflicts and improve the conditions of the labour market.

While land reclamation did to some degree achieve the first three goals, the policy failed miserably with respect to the last intended goal. Reclamation was intended to enable the displaced population of farm labourers to become a new class of farmer. However, the prohibitive capital costs of reclamation and the failure to modify traditional repressive property and productive relationships thwarted any progress for the rural peasantry.

The new lands fell mostly into the hands of propertied interests who had, or could secure, the financial means to participate in reclamation. They in turn ceded parcels to landless peasants willing to colonise and work the land *(colonia parziaria)*. *Mezzadria* contracts prevailed on farms averaging 15-20 ha[1]. The typical contract lasted 6 years and the peasant farmer was little more than a farm labourer as he was obliged to maintain the farm and plant crops dictated by the owner who would supply necessary capital (including farm buildings and residences), farm machinery, equipment and draught animals (Marian 1993). It was not until after World War II that the lot of the peasant farmer gradually improved when industrialisation created greater employment opportunities for the rural poor as well as establishing the impetus for the second stage of land transformation in the region.

2. Second Phase of Landscape Transformation

Starting in the 1960's, Italy experienced rapid industrialisation, economic growth and modernisation. This transformed the country from a poor agrarian nation to a wealthy industrial nation. This "economic miracle" also extended to the agricultural sector. Within the span of a couple of decades this sector was transformed from its traditional subsistence and labour intensive state, to a modern mechanised form utilising the newest available methods and technology. Further discussion on the transition of agriculture is included in Chapter 6.

Immediate and long-term results of this economic transformation on agriculture were huge increases in agricultural productivity, the shift in rural employment from agriculture to other economic sectors, and radical modifications to agricultural landscapes. Between 1951 and 1985, the gross agricultural product increased in real terms by 117 percent, and the gross value added by 76 percent, while the number of agricultural workers decreased by 73 percent. Furthermore, there was an increase of 428 percent in intermediate consumption (agricultural purchase of inputs and services from other sectors such as seeds, fertilisers, pesticides, energy), and investment in

[1]*Mezzadria* contracts were preferred by landowners as in the early part of the century they comprised three fifths of all farms in the Lower Piave Consorzio area. Other forms of organization included owner-operated farms and those operated using salaried labour (Fassetta 1977). See also section 6.2.

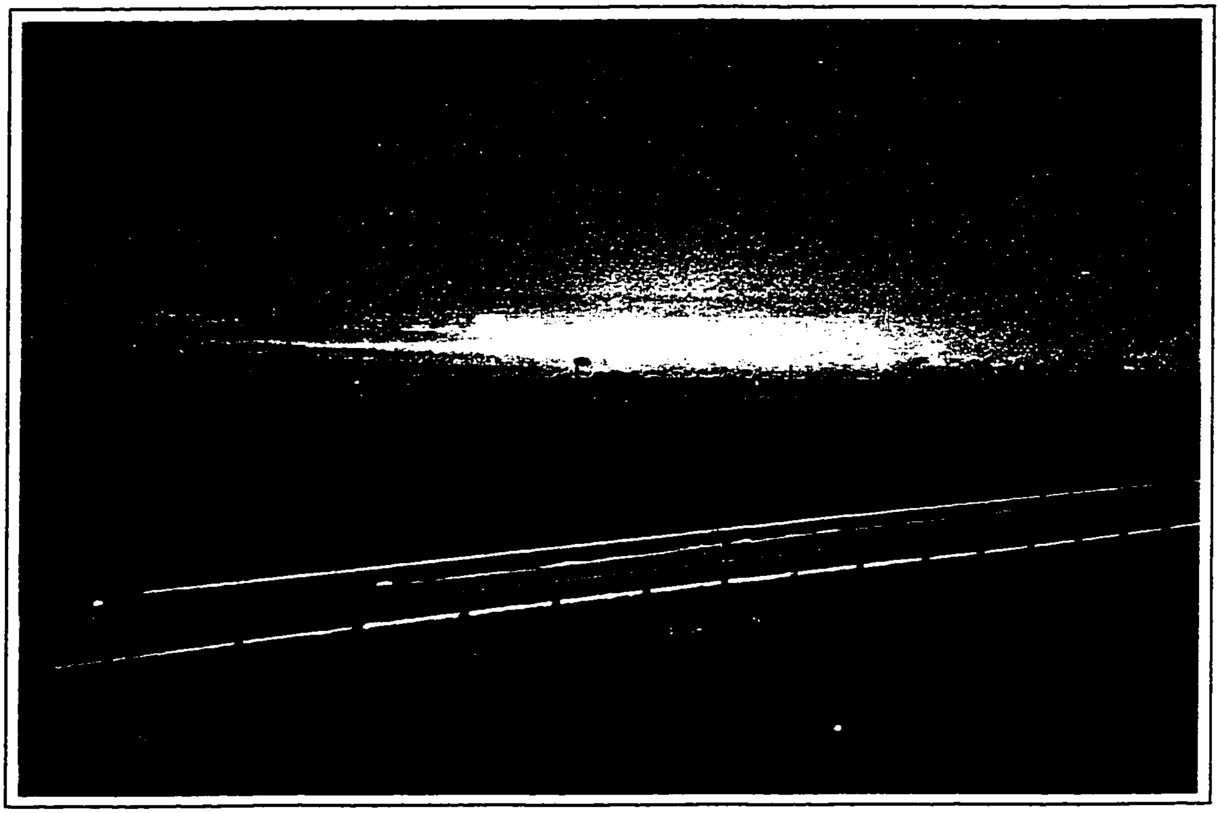
farm equipment expanded by as much as 237 percent (Galante & Sala 1993). Transformation of agriculture is discussed further in Chapter 6.

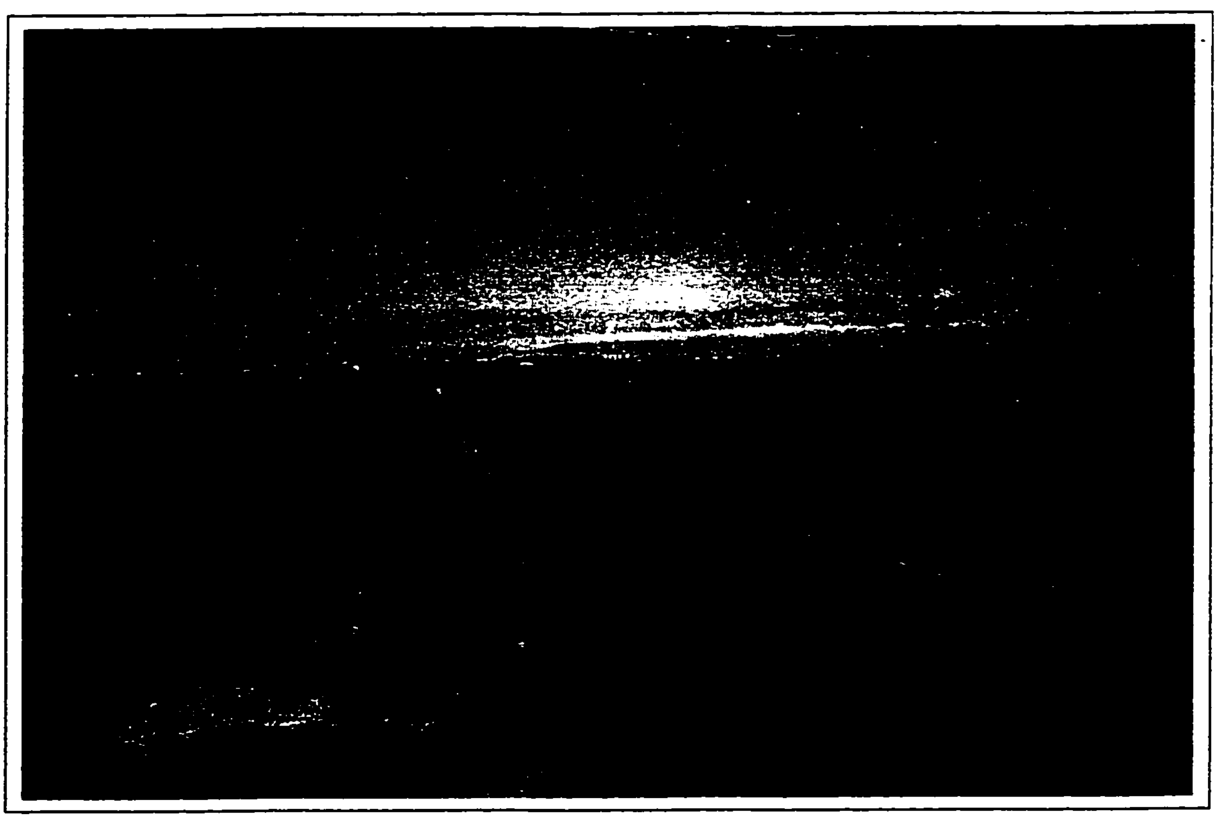
These economic and social changes drove the second phase of landscape transformation, where the overall landscape evolved from that depicted in Maps 5.2 to that depicted in map 5.3. This transformation saw the gradual elimination of piantata and closed fields to create the present modern landscape. The modern landscape (Map 5.3) consists almost entirely of treeless open fields, crossed by parallel drainage ditches every 50 metres or so, and interrupted only by roads, clusters of building, dikes and canals. Monocultures of corn and soybean crops dominate the landscape, which is also interspersed with occasional vineyards, orchards and fields of wheat and sunflowers.

Figure 5.1 provides pictorial images of this landscape of open fields *(campi estesi ed aperti)*. A bird's eye view of these landscapes is also provided by Figure 6.4 in Chapter 6. The agricultural landscape is largely devoid of vegetation with the exception of the occasional windbreak, popular plantation, clusters around farm buildings, and vegetation in settlements and along major roadways. While some vegetation is today being planted in rural areas, this situation is still typical of 1990's landscapes. It is also for the most part characteristic of all highly governed landscapes of the northeastern Italian coastal zone.

The piantata in particular was doomed by economic modernisation of the country following the Second World War. Immediately following reclamation, the traditional piantata was established on much of the new farmland, as subsistence farmers remained the primary producers on a large segment of the territory. The ecological and productive functions provided by the piantata were still relevant given the farm economy was relatively unchanged from previous eras. However, increasing mechanisation, chemical fertilisers, and desire for increased economic efficiency and productivity rendered the piantata, and its functions, obsolete (Provincia di Venezia 1994a). This factor, combined with the hindrance traditional piantata posed to mechanised cultivation, resulted in its elimination not only in this area, but also across the entire

Figure 5.1
Open Field Landscapes





Northern Italian Plain.

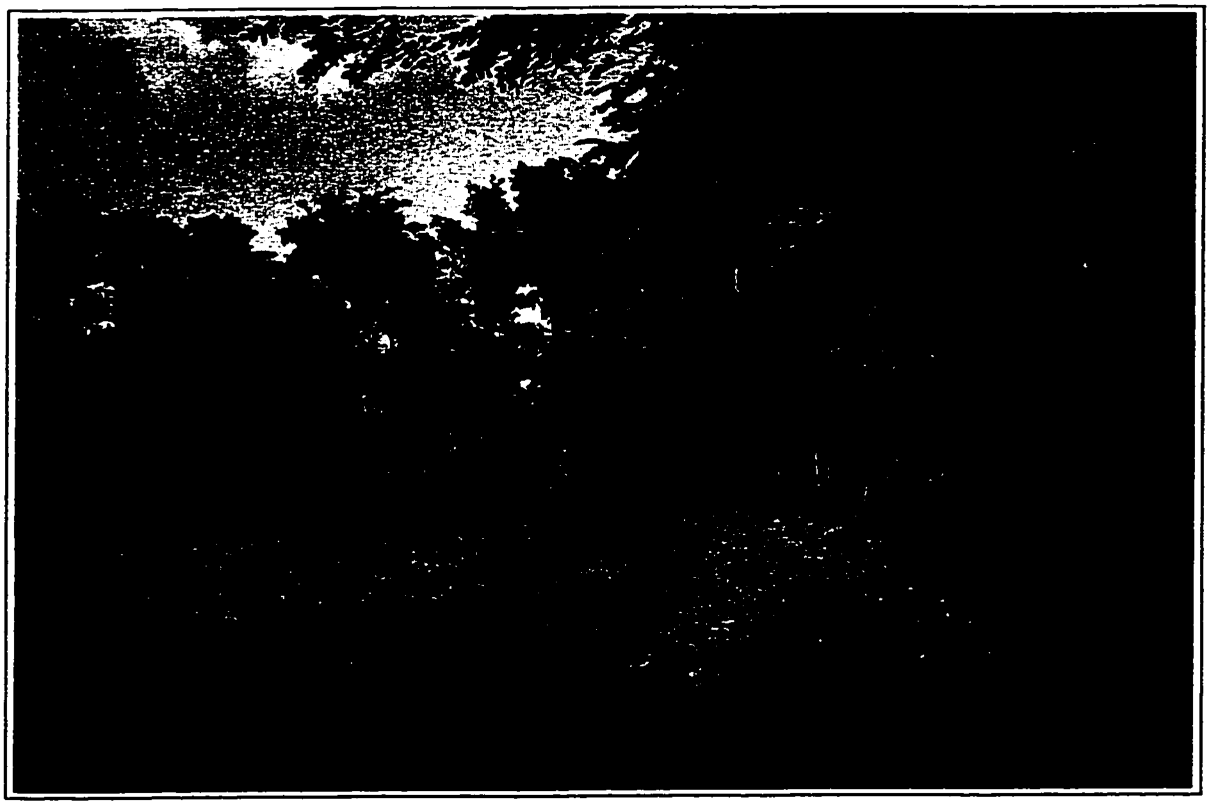
The removal of hedgerows and vegetation to create vast open fields quickly followed the elimination of the piantata. As with piantata, the practical functions served by the hedgerows (e.g. fuelwood, delimiting property limits) became irrelevant with the transformation of agriculture. Hedgerows occupied valuable strips of land, created shade, and interfered with the establishment of larger fields favoured for greater production and efficiency. Also, many of the irrigation and drainage ditches, which traditionally were lined with trees and vegetation, became redundant with the restructuring of fields and were removed. Moreover, the required regular maintenance (excavation) of ditches, once accomplished by human labour, was hindered by the presence of trees, which obstructed the movement of machinery now used to excavate the ditches. And lastly, the economic and practical rationalisations for removal of hedgerows created or reinforced an attitude that hedgerows were now superfluous and had to be "cleaned out" as they interfered with modern agriculture (Zanetti 1988).

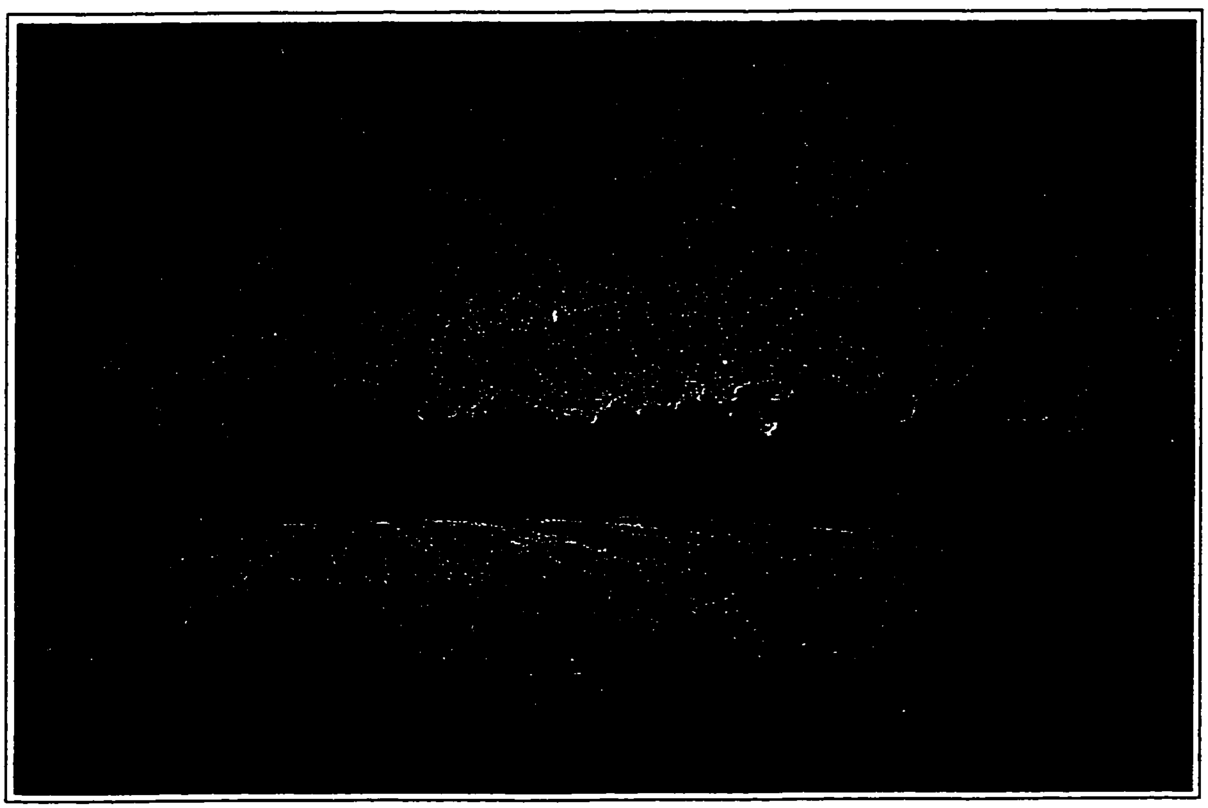
This combination of factors spurred the creation of the vast open fields of the present day Lower Piave. An open field regime also tends to predominate throughout the flat terrain of the lower Venetian Plain, while towards the upper plain, the landscape still tends to retain a more closed field form. On average, fields have tended to become larger as the amount of hedgerows has been estimated by one source to have decreased from 250 metres per hectare at the beginning of the century, to around 50 metres per hectare today (Vianello & Vita 1994). An illustration of a typical closed field landscape/cultivation system in the upper plain today is provided by Figure 5.2. With the addition of rows of piantata subdividing fields, this scene would be typical of most of the Venetian Plain prior to the modernisation of agriculture.

3. Summary of Landscape Transformations

Table 5.1 provides a simple numeric summary of 20^{th} century landscape transformation in the Lower Piave. Also included are land cover areas for the 1833 period for comparative

Figure 5.2
Closed Field Landscapes





purposes. Aside from the two major transformations which clearly emerge from area figures, some other landscape characteristics and trends are also notable.

Table 5.1
Land Cover Composition Percentages

	1833*	1908-10	1960-69	1983-90
Piantata	30.2	33.0	8.8	0
Closed Fields	—	9.4	36.2	0.4
Open Fields	—	4.4	45.6	90
Pasture	10.4	5.9	0	0
Marsh	58.1	40.7	0.2	0.2
Woods	—	0.5	0.8	0.35
Beach\Sand Dunes	1.1	0.7	0.4	0.3
Urban	0.1	0.8	3.0	5.8
Unclassified Terrain	—	4.6	5.0	2.8
Total	100	100	100	100

*Land Cover Composition Percentages for entire Lower Piave Area taken from Map 3.6.

One important finding is that newly created agricultural landscapes in the immediate post reclamation era were similar to landscapes of the pre-modern agricultural era. The establishment of piantata and closed fields on much of the newly reclaimed land meant that these landscapes were still ecologically and culturally similar to traditional Venetian Plain agricultural landscapes. It was with the post World War II transformation of agriculture that landscapes took their present modern form and lost any similarity and connection to past landscapes.

Another characteristic trend is the virtual absence of other natural terrestrial areas such as woods and dunes. These features have gradually diminished by the 1980's, and are entirely confined to the littoral belt. In the case of woods, the increase in the 1960's is attributable to the planting of woods in coastal dune areas by the State government during the first 40 or so years of the century. The planting of both pine and mixed woods in coastal areas was part of overall land reclamation efforts. The afforestation of coastal areas was intended mainly as a windbreak to prevent the blowing of sand into neighbouring agricultural areas and to stabilise coastal dunes.

These replanted areas, however, were gradually diminished by coastal recreation development in the modern era (Del Favero *et al.* 1989).

The decline of dunes is also related to the trend toward increased urban development related to recreational land use along the littoral zone. This type of development has contributed toward the decline of beach and dune areas as construction has taken place on these areas. Another significant trend is the substantial increase in urban area/land use as a result of increased industrial and tourism activities, combined with increased residential development arising from moderate population growth (see table 6.5 in Chapter 6).

5.3 QUANTITATIVE ANALYSIS OF LANDSCAPE CHANGE

This section examines 20th century landscape transformations using the diversity and dominance indices discussed in the landscape ecology review in Chapter 2. This analysis provides a more quantitative view of landscape change compared to the previous section, which was intended to illustrate the two major phases of land transformation and their determining factors. Furthermore, the significance of the second phase of landscape transformation is discussed from an ecological and "health" perspective.

For this particular analysis, data values have been derived from the information base developed from the digitised topographic maps. For each year/period, a function within **MapInfo** was used to aggregate polygon areas for each specific land cover and cultivation system category. A polygon is defined as the continuous area occupied by a particular land cover or cultivation system. All polygons represent land cover and cultivation system categories digitised from the topographic maps. Continuous areas of similar land cover types, as illustrated in Maps 5.1, 5.2 and 5.3, represent the polygons for which area values are aggregated. These figures were then transferred to spreadsheets and imported into SPSS. SPSS then calculated total land area covered by each land cover/cultivation system type, as well as diversity and dominance index values.

Table 5.2 provides a breakdown of the quantitative analysis. Total land areas are significant for the calculation of diversity and dominance indices given these measures are based on proportional area of land cover types. Concerning simple area values, the trends noted in the previous section also emerge from the quantitative analysis.

Table 5.2
Landscape Diversity and Dominance

Land Cover	Total Land Area (sq. km)		
	1910	1960's	1980's
Beach	1.19	0.68	0.49
Closed Fields	16.05	52.71	0.77
Marsh	69.33	0.36	0.54
Open Fields	7.47	77.32	152.78
Pasture	12.60	0	0
Piantata	56.26	14.88	0
Urban	1.44	5.05	9.86
Woods	0.92	1.30	0.61
Diversity	1.40	1.13	0.32
Dominance	.679	.816	1.47

The diversity values from Table 5.2 indicate how landscape heterogeneity has decreased over time. With diversity values, the larger the value, the more heterogeneous the landscape. The diversity value for the 1980's is extremely low which reflects the extreme measure of landscape simplification. The dominance figures also confirm the trend toward the dominance of one, or few landscape types[2].

Normally, measures of diversity and dominance have been used in relation to specific land cover types (e.g. urban, agricultural, transitional, pasture, deciduous and coniferous forest) (Turner & Ruscher 1988; O'Neill *et al.* 1988; Medley *et al.* 1995), rather than

[2] To summarise what was outlined in Chapter 2, the **dominance** figure is achieved by adding Hmax to the diversity value, which is usually a negative value. Hmax is the maximum diversity when all land uses are present in equal proportions. Large dominance values indicate a landscape that is dominated by one or few land uses.

with particular cultivation systems that are included in this case (e.g. piantata, closed fields, open fields). In this regard, the meaning of diversity and dominance measures requires additional scrutiny and interpretation because of the unorthodox use of cultivation systems as additional land cover types.

A diverse landscape in this context can mean one with a diversity of land cover types as was evident in early periods (e.g. cultivation, marsh, dunes, pasture). A diverse landscape can also mean one with a diversity of cultivation systems (piantata, open fields, pasture, closed fields), with additional land uses in other categories (marsh, woods, urban). The latter type of diversity was evident in the 1960's. It is significant that this emphasis on specific cultivation systems still produces dominance and diversity values comparable to values derived from studies of U.S. agricultural landscapes which focus on land cover characteristics (Medley et al. 1995; Turner & Ruscher 1988). The exception is the 1980's values, which reflect extremely simplified landscapes and the overwhelming dominance of one cultivation system.

Landscape diversity in both these terms has implications for biophysical landscape health, as was discussed in section 2.3 and also emphasised by Medley *et al.* (1995) and Paoletti *et al.* (1992). Diverse agricultural landscapes with a variety of land cover types are better able to cope with stress (e.g. from pests and disease). They are also considerably more amenable to the maintenance of biodiversity compared to landscapes dominated by cereal crop monocultures. Furthermore, landscapes characterised by a diversity of landscape types (e.g. piantata, closed fields, pasture) are also more favourable from an ecological perspective as they contain structures that allow floral and faunal communities to coexist with agriculture. This then promotes species health and diversity within cultivated landscapes.

On the other hand, agricultural landscapes dominated by piantata or even closed fields are not necessarily detrimental to the health of these landscapes. Closed field and piantata cultivation systems are favourable from an ecological and "health" perspective because of the abundance of structures which essentially comprised the "natural" habitat in traditional Venetian agricultural landscapes. Therefore, dominance values, and their relation to landscape health, must be interpreted based on what types of landscapes dominate. Nonetheless, the high dominance value evident during the 1980's, and the pervading open field cultivation system suggests that landscapes have been impoverished compared to their condition in the pre-modern era. The values from Table 5.2 are later applied in Chapter 7 when characteristics and thresholds of landscape health are proposed.

5.4 CONCLUSIONS ON LANDSCAPE EVOLUTION, TRANSFORMATION AND GOVERNANCE

At this stage, it should be clear how the Lower Piave became a highly governed landscape through reclamation and how landscapes were subsequently transformed during the later part of the century. The highly governed landscape is the basis for the remainder of the dissertation. The reader should also now be familiar with the general biophysical nature of both traditional and modern landscapes, as well as the significance of recent landscape transformation in terms of key the ecological principles mentioned in Chapter 2.

The last issue to be examined in this chapter concerns some significant findings regarding the historical and cultural context of landscape governance. This carries over from Chapter 3. While the 20th century was the period of transformation to a highly governed landscape, transformation was tied to historical and cultural developments of earlier periods described in Chapter 3. Therefore what follows are a number of important conclusions regarding landscape governance drawn from the historical accounts of landscape evolution and transformation up to the present day. These are regarded as essential considerations when formulating biophysical landscape health given it should reflect the historical and cultural context of the study region.

There are four main conclusions on landscape governance:

1) The idea and belief that humans can govern the landscape to meet their needs has a long tradition in this region and can still be viewed as a normal part of the culture;

2) Land governance as it was practised prior to the post World War II era of modernisation was not necessarily incompatible with the long term health of traditional agricultural landscapes;

3) Drainage restructuring and engineering represented, and remains a dominant component of land governance culture;

4) Land reclamation is generally viewed in the region as a positive social and economic achievement even in light of infrastructure costs and elevated flood risks for inhabitants.

Concerning the first point, the Romans can be credited with establishing the precedent that humans could successfully alter, manipulate, and govern the landscape for their own benefit. While their own method of organisation (centuriation) was abandoned and dismantled during the Middle Ages, many of the landscape patterns and elements put into widespread use by the Romans were perpetuated until at least the early part of the 20th century. During the first half of the 20th century, subsistence agriculture maintained cultivation systems which were ideally suited to its needs. In fact, while the piantata has largely been eradicated during the latter part of this century, the landscape of closed fields and systematic drainage remains evident today in many parts of the upper Venetian Plain.

It is also important to emphasise that the landscape system perpetuated over the ages needed its own form of maintenance. This consisted of periodic excavation and cleaning out of drainage ditches and canals, periodic cutting and thinning of vegetation along hedgerows, and maintenance of piantata structures. This combined with the organisation imposed on the landscape (e.g. drainage and field systems) constituted landscape governance. Even in the later 20th century with mechanised agriculture and open fields, the maintenance of landscapes is still required except that it is practised within a more modern context. For example, drainage systems still need to be periodically excavated as they become clogged from slope failures, sedimentation, and aquatic vegetation growth. Today, they are excavated using machines rather than by hand and excessive vegetation along canal banks is cleared using herbicides.

As to the second conclusion, two specific bodies of evidence suggest it. First, the fact that features of Roman centuriation have persisted to this day suggests an ecological viability is associated with these structures and the practices that sustained them. It might also be argued that over the long term these landscapes represented an **equilibrium** condition sustained by subsistence agriculture. The landscape was perpetuated so long as farmers tilled fields, thinned and cut hedgerows, managed grazing animals, and maintained the field drainage system. Otherwise, the land would have reverted to meadows and then possibly regenerate to another climax state as happened during the Medieval era.

From modern landscape ecology, we also know that certain landscape structures promote ecological integrity. Many of these structures were characteristic of traditional Venetian landscapes. While it is likely that material and practical needs of early agriculture dictated landscape organisation and governance, the evidence suggests that a long-term ecological viability was both consciously and unconsciously built into agricultural landscapes. This arose out of the necessity of sustaining landscapes and their capacity to provide "ecological" services essential to human survival.

As to the third point, the tradition of hydraulic restructuring began with the Romans and was entrenched in Venetian culture by actions of the Venetian Republic. The Republic undertook wide scale hydraulic restructuring in order to preserve the lagoon from siltation, mitigate constant flood risk in the lower plain, supply irrigation water, and to establish agricultural land in poorly drained areas (Cosgrove 1990 & 1993). Hence, hydraulic engineering became an important component of environmental management given not only practical problems, but also the philosophy that nature could be manipulated and tamed to serve human needs.

The desire to become a "modern"[3] country is credited with providing

[3]The philosophy and goal within the ruling government at the time was the desire to take Italy from a poor agrarian nation to a modern industrial one. For example, reclamation and energy projects of the early 20th century were regarded as an important step toward country modernisation for the social and economic improvements they were expected to bring (Zanetto *et al.* 1996).

significant impetus for the reclamation of coastal lowlands in the 20th century (Zanetto *et al.* 1996). This was also undoubtedly influenced by the tradition of hydraulic restructuring. While the influence of this variable on widespread reclamation is impossible to know for certain, it is clear that intentionally or not, the tradition of hydraulic restructuring was carried over into the 20th century through land reclamation. Today, the need to permanently manage drainage works in reclaimed areas ensures that hydraulic restructuring will remain a dominant aspect of land governance culture.

The last conclusion extends from the previous one. Despite the economic costs of reclamation and continued maintenance of infrastructure, reclamation is generally viewed by Italian society as a positive development for the region. While local interests acknowledge permanent flood risk facing humans and property, this is countered by the widespread belief that reclamation has provided tangible benefits. These include economic development through agriculture and the eradication of malaria, which once posed a serious hygienic problem near marshlands. In terms of flood hazards, the philosophy of modifying the hazard to protect human interests was culturally entrenched in the region by the actions of the Venetian Republic over its 700 years of dominance. This philosophy was perpetuated by land reclamation in the 20th century and persists to this day[4].

In conclusion, these four findings are believed to have significant implications for interpreting landscape health for the Lower Piave. Fundamentally, historical landscape and cultural considerations should be incorporated into any interpretation of biophysical landscape health. Landscape health is contextual, and it is probably flawed to interpret landscape health outside these cultural parameters. Ultimately, the intention is to develop an interpretation of landscape health which is not only relevant to the biophysical context of the study area, but which

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[4]For further description regarding the cultural entrenchment of hydraulic engineering and reclamation, see Cosgrove (1990 & 1993) and Zanetto *et al.* (1996).

is also relevant to its historical and cultural context. For this reason these findings have been outlined. Their importance becomes evident when an appropriate interpretation of landscape health is formulated in Chapter 7.

Chapter 6:
Assessing Lower Piave Landscapes

6.1 INTRODUCTION

This chapter examines the state and condition of four key Lower Piave landscape elements and their trends over time. The four landscape elements to be analysed and assessed include the **agricultural systems, surface water drainage, water quality** and **vegetation**. These have been identified as the most significant and important landscape elements in the Lower Piave. Their significance was briefly mentioned in Chapter 4.

Agriculture represents perhaps the most significant landscape element given it is the dominant land use activity, and is thus closely interconnected to other key landscape components. Agriculture is also significant for the fact that other than the 1:25,000 topographic maps, agricultural land use data represents the best primary data available to assess landscape (and health) trends over time. Through a variety of statistical compendiums, there are comparable statistics on agricultural land use and cropping patterns extending over the last 100 years in the province of Venezia *(Provincia di Venezia)*.

Water is a key element in any landscape given it is vital to all living organisms, It is also a vital resource with respect to human needs above and beyond subsistence (e.g. industrial, irrigation use). In the Lower Piave, land drainage takes on a special importance because control of this element is the most critical part of landscape governance given the area would revert to marshes without human intervention. Land drainage is also closely linked to landscape structural features and agricultural land use. Water quality is an important issue in most intensely utilised agricultural landscapes. Water quality is linked to both agricultural practices and landscape structure as will be demonstrated later in the chapter.

Vegetation species and structures are also an essential component of the overall health of agricultural landscapes given they provide essential ecological functions for a full range of biological organisms including humans. This was demonstrated to some degree in the landscape history where throughout the pre-modern subsistence era of agriculture, humans relied on and exploited the ecological and material functions provided by vegetation. As well as examining trends related to vegetation, this chapter will illustrate in greater detail the important role of vegetation in agricultural landscapes.

6.2 AGRICULTURAL SYSTEMS

The analysis of agriculture is comprised of two parts. The first part examines the evolution of agriculture in the 20th century through an analysis and comparison of land use patterns, cropping patterns, and the conduct of agriculture (organisation, methods/ technology, inputs) during both eras. The second part assesses the sustainability of agriculture using a framework based on Table 2.6. As stated in Chapter 4, the emphasis is on biophysical/landscape and farming system characteristics of sustainability. The overall objective of this analysis is to assess and compare the sustainability of agriculture in both the pre-modern and modern era. This analysis is ultimately useful for relating farming systems to biophysical landscape health.

1. Evolution of Agricultural Systems in the Lower Piave Area

Chapter 5 illustrated landscape transformations during this century. Agriculture and land use statistics available for a number of points in time since 1880 and reflect these changes. Tables 6.1 and 6.2 illustrate agricultural land uses for two municipalities or *comuni (Noventa di Piave, Eraclea)* [1], which geographically fall entirely within the Lower Piave area (Map 6.1).

[1] These two comuni have been selected as a representative sample of the Lower Piave area as they both fall entirely within the Lower Piave compared to others which extend beyond the boundaries. Additionally, these two comuni represent two different types of landscape evolution and thus have additional comparative value. Noventa di Piave is above sea level and did not experience land reclamation, while the majority of territory in Eraclea is land reclaimed during this century.

Map 6.1: Municipalities in the Lower Piave Area

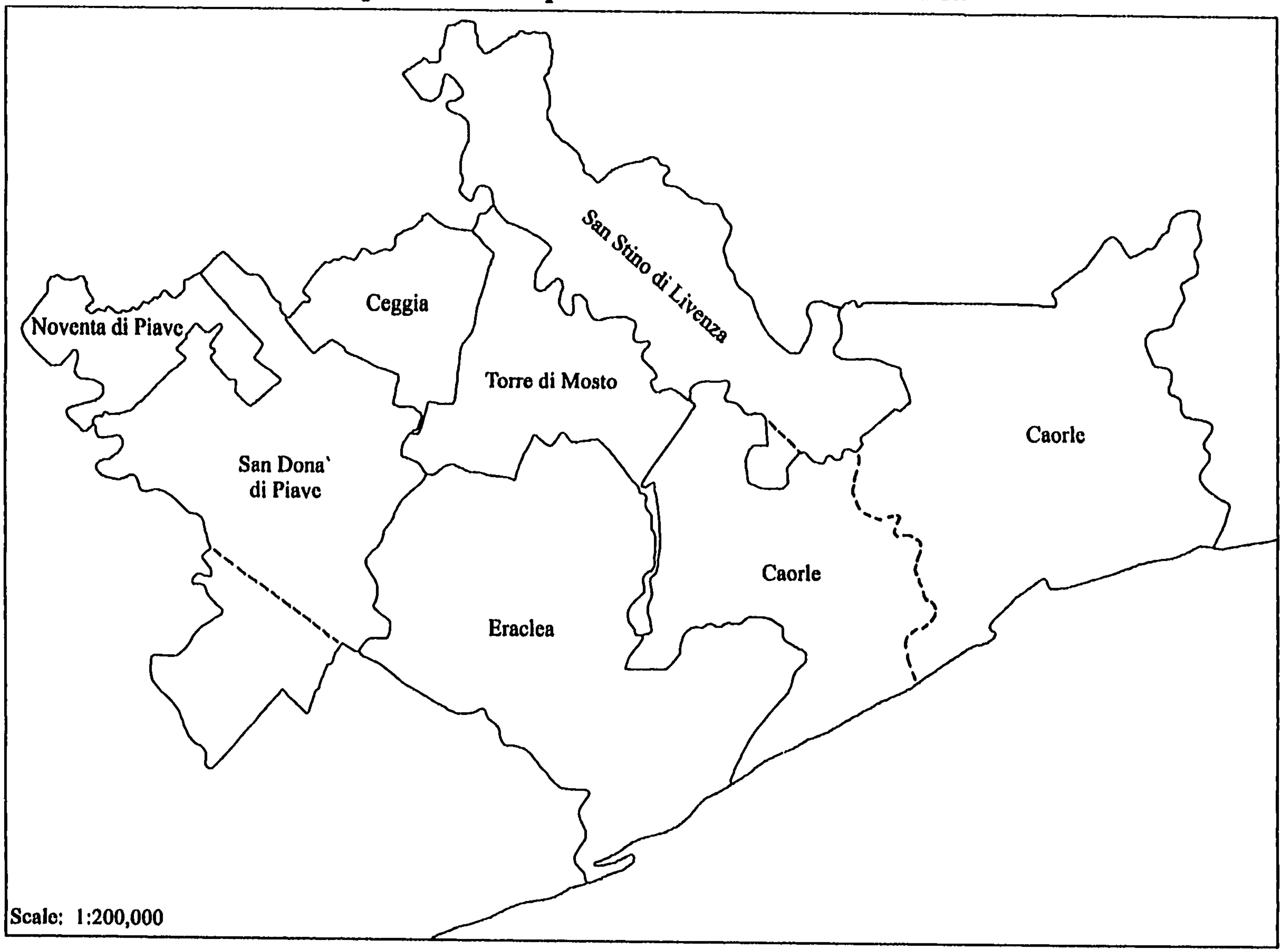


Table 6.1
Agricultural Land Use Percentages - Eraclea

Land Use Type	1880-1881	1929	1970	1990
Open Cropland *(seminativi nudi)*	4.3	62.4	71.2	83
Crops in Piantata *(seminativi arborati)*	43.2	30.4	NA	NA
Permanent Cultivations (vineyards, orchards) *(coltivazioni permanenti)*	NA	1.8	15.1	6.1
Pasture and Meadows *(prati e pascoli)*	52.4	5.1	0.4	0.2
Tree Plantations *(piopette)*	NA	NA	0.4	.08
Woodland *(boschi)*	0.0	0.3	1.1	0.6
Other[2]	0.3	0.0	12.2	9.9
Total	100%	100%	100%	100%

Table 6.2
Agricultural Land Use Percentages- Noventa di Piave

Land Use Type	1880-1881	1929	1970	1990
Open Cropland *(seminativi nudi)*	4.0	5.6	58.4	68.1
Crops in Piantata *(seminativi arborati)*	81.5	82.8	NA	NA
Permanent Cultivations (vineyards, orchards) *(coltivazioni permanenti)*	NA	5.3	29.8	18.5
Pasture and Meadows *(prati e pascoli)*	14.1	3.6	0.7	0.1
Tree Plantations *(piopette)*	NA	NA	NA	0.3
Woodland *(boschi)*	0.0	0.9	1.5	0.4
Other	0.3	1.8	9.6	12.6
Total	100%	100%	100%	100%

Sources: Sormani-Moretti 1880-1; Istituto Centrale di Statistica del Regno d'Italia 1935; ISTAT 1972a, 1985 & 1991a.

[2]The meaning of "Other" varies as it is used to round out figures given there are slight variations on how agricultural land was classified in each census period. For 1970 and 1990, other refers to land either not destined for agriculture or land not currently under production. For 1929, it represents land not currently under cultivation, but still providing a spontaneous agricultural product (e.g. fodder, wood product). For 1880-1 it represents areas of gardens and vineyards.

Each figure in the tables represents a **percentage** of the total non-urban territory devoted to what is known as "productive land use". This includes cultivation, tree plantations and woodland. The dates have been chosen based on agricultural censuses and to match the periods of the previous landscape analysis. Table 6.3 provides percentage figures on cropping patterns for both comuni under examination. These three tables provide important information as to the character of agricultural systems in the pre-modern era.

Tables 6.1 and 6.2 furnish important indications as to both landscape and land use trends during different points in time. The most important trend is that of the elimination of the piantata and pasture, and the expansion in the last 30 years of open cropland. Open cropland is fields of single or mixed crops without any subdivision by piantata. The total demise of the piantata is indicated by the fact that the category does not exist in the latter two censuses and is consistent with the analysis from Chapter 5.

Table 6.3 Cropping Patterns - Noventa di Piave, Eraclea

Crop Type as % of Total Productive Agricultural Land	1929 Noventa di Piave	1990 Noventa di Piave	1929 Eraclea	1990 Eraclea
Cash/Sown Crops: *(seminativi)*	88.4	78.57	92.8	92.93
Corn	27.6	26.67	31.6	34.86
Soybeans	0.0	34.03	0.0	40.39
Other *(Wheat, Rye, Oats Barley, Rice, sugar beet, rice, etc.)*	18.5	12.61	32.5	14.68
Forage Crops/ Fallow[3]	40.0	5.26	28.2	2.67
Vegetable/ Garden Crops	2.1	0.10	0.5	0.33
Vineyards	3.3	21.11	0.8	5.16
Orchards	0.5	0.22	0.4	1.70
Other	8.0	NA	5.9	NA
Total	100%	100%	100%	100%

Sources: Istituto Centrale di Statistica del Regno d'Italia 1935; Provincia di Venezia 1994b.

[3]In the 1929 census, forage crops and fallow are classified as one crop category, while in 1991 this category only applies to forage crops.

Table 6.3, indicates significant changes in cropping patterns which reflect the transformation of agriculture during the latter half of this century. In the earlier part of the century, there existed a more diverse cropping pattern with significant portions of land devoted to fodder crops and fallow which were regularly used to help maintain soil fertility in the absence of chemical fertilisers. In the modern era, there is a less diverse cropping pattern with a huge increase in the cultivation of soybeans at the expense of other cash, fodder crops and fallow. Corn production, long a staple of rural peasant populations, has remained relatively constant. Vineyard area has increased substantially and is likely a substitution for the grape production lost from the elimination of piantata.

Tables 6.1 and 6.2 also provide us with some important information regarding early post-reclamation agricultural land use. Despite similar land use trends between Noventa di Piave (unreclaimed) and Eraclea (reclaimed), there are some notable differences as a result of processes associated with land reclamation.

Around 1880, for example, larger areas of pasture and meadow existed in Eraclea compared to Noventa di Piave. This is attributable to the fact that hydraulic and *colmata* reclamation during the latter half of the 19th century initially produced significant areas of poorly drained marginal lands suitable only for pastoral activities. These later became productive through wide-scale mechanised drainage.

Around the 1929 period, there is also markedly more open cropland for Eraclea compared to Noventa di Piave, where piantata dominates agricultural landscapes until its elimination in the modern era. A breakdown of open cropland compared to piantata is given in Table 6.4 for all the comuni falling within the Lower Piave area. The table illustrates how piantata comprises a larger percentage of the land in comuni with more older established agricultural landscapes (e.g. *Ceggia, Noventa di Piave, San Dona` di Piave, Torre di Mosto*), compared to the mostly reclaimed comuni *(Eraclea, Caorle)*, where open fields were imposed on a larger proportion of land.

Nonetheless, Table 6.4 shows that considerable piantata was established on reclaimed terrain given the persistence of traditional subsistence agriculture.

Table 6.4
Open Cropland Vs. Piantata as a % of Total Land Devoted to Agriculture - 1929

Comune *(Municipality)*	Open Cropland (%)	Crops in Piantata (%)
Caorle	60.5	19.2
Ceggia	15.2	71.0
Grisolera (Eraclea)	62.4	30.4
Noventa di Piave	5.6	82.8
San Dona' di Piave	24.3	61.5
Torre di Mosto	30.9	57.4

Source: Istituto Centrale di Statistica del Regno d'Italia, 1935.

In summary, pre-modern agricultural systems emphasised more diverse cropping patterns and cultivation systems. This reflected the predominance of subsistence agriculture and the absence of chemical fertilisers, which became available in the modern era. This necessitated the use of crop rotation and leguminous crops to restore fertility. Furthermore, fodder crops were required to feed farm animals (cattle, horses, and oxen) that provided a number of necessary services, including manure and animal power for plowing fields and pulling wagons.

Based on some of the health and integrity principles discussed in Chapter 2, pre-modern agricultural systems appear to promote "healthy" landscapes from a biophysical standpoint. The existence of piantata and closed field cultivation systems indicate agricultural systems which foster relative biological diversity - a requisite of ecological integrity. These also play an important role in sustainable agriculture as illustrated in section 2.2. Diverse cropping patterns are also essential for sustainable agriculture in the absence of chemical inputs.

An illustration of the pre-modern farming system is provided by Figure 6.1. This depicts a typical crop rotation scheme recommended during the first few years after the initial land reclamation (for a 100 ha farm). In this scheme, the first three years of rotation correspond with the preparation of the farm for long-term cultivation (levelling and proper draining fields, tree planting, etc.). The last two years illustrate the implementation of a classic rotation scheme characterised by the growing of wheat and corn, which grew best on level fields. This practice was complemented with the use of mineral fertilisers (P, K and Lime) and the limited supply of animal manure available (Sattin 1922; Bortolotto 1932)

Figure 6.1
Typical Rotation Scheme for Newly Reclaimed Lands[4]

	25 ha	25ha	25ha	25ha
Year 1	Fallow	Clover	Alfalfa	Oats with Alfalfa
Year 2	Oats with Clover	Wheat	Alfalfa	Clover and Alfalfa
Year 3	Clover	Corn & Sorghum or Sorghum	Alfalfa	Clover with Wheat

	20 ha	20ha	20ha	20ha	20ha
Year 4	Wheat or Oats with Alfalfa	Wheat or Oats	Wheat with Clover	Corn	Clover
Year 5	Alfalfa	Corn	Clover	Wheat with Clover	Wheat

Source: Sattin, 1922.

Within the larger picture, changes in land use and cropping patterns illustrated in Tables 6.1, 6.2 and 6.3 are the result of the post World War II transformation of Italian society from a relatively poor agrarian society to a modern industrial one (Provincia di Venezia 1994b). This transformation had social, economic and technological dimensions. These interacted to bring about changes in the structure and conduct of agriculture which led directly to landscape transformation. Economic and technological changes also had a huge impact on sustainability. Another variable playing a large role in the transformation was institutional factors such as Italian government policy and Italy's membership in the European Community (now European Union).

[4]It is important to emphasise that the 25ha parcels are used for illustrative purposes when the scheme could apply to much smaller parcels. Furthermore, rotations did in fact vary depending on local conditions and the amount of other fertilisers available.

The dimensions of agricultural transformation as well as the role of institutional factors are now reviewed.

In the first place, the industrialisation of the country after World War II brought about profound social changes. These along with technological changes altered the relationship between humans and the land. Most significantly, rapid industrialisation and economic development created new opportunities for the subsistence level farmer. The repressed landless peasant and farm labourer now had better employment options in the industrial and tertiary sector. This, not surprisingly, led to a wholesale exodus of the farm population to other economic activities. Technological developments and economic growth also allowed increased farm mechanisation, which decreased the need for human labour.

Table 6.5
Employment Change - Noventa di Piave, Eraclea

1961 Employment as % of Total:	Noventa di Piave		Eraclea	
Agricultural Sector	27.2		57.7	
Industrial Sector	50.0		30.4	
Tertiary Sector	23.7		11.9	
Total Employed	100% (2,062)		100% (3,924)	
1991 Employment as % of Total: *(1961-91 % change in parentheses)*				
Agricultural Sector	4.3	(-81.3)	8.8	(-80.7)
Industrial Sector	49.1	(+15.6)	42.9	(+78.2)
Tertiary Sector	46.5	(+141.2)	48.2	(+410)
Total Employed	100% (2,427)	(+17.7)	100% (4,944)	(+25.9)
1991 Population *(1971-1991 % change in parentheses)*	5,733	(+13.8)	11,841	(+10.2)

Sources: Consorzio di Bonifica Basso Piave 1991; ISTAT 1994.

Table 6.5 outlines employment change in two Lower Piave comuni and a precipitous drop in employment in the agricultural sector is evident. The trend of steep employment drops in agriculture is also indicative of the entire region. Also notable is the great increase in tertiary sector employment in Eraclea. This is attributable to coastal development related to tourism and recreation during this period.

Along with employment shifts, there was a significant population shift from scattered rural dwellings to town centres and urban nodes. Table 6.6 illustrates the rural-urban population shift for Noventa di Piave and Eraclea. From 1951 to 1991, there has been a radical shift from rural habitation (in rural homes dispersed across the countryside), to habitation in the main town centre and urban nodes in each comune[5]. This shift also reflected post W.W. II economic and technological changes which transformed economy and agriculture.

Table 6.6
Population Shifts – Noventa di Piave, Eraclea

	Noventa di Piave		Eraclea	
	1951	1991	1951	1991
Pop'n in Main Urban Centre and Other Urban Nodes	52.8	79.6	24.2	78.2
Pop'n in Scattered Homes	47.2	20.4	75.8	21.8
Total Population in Brackets	100% (6330)	100% (5733)	100% (12839)	100% (11841)

Sources: ISTAT 1956; ISTAT 1994.

Industrialisation and the corresponding exodus from the land had a direct impact on agricultural landscapes and agricultural systems. Specifically, the decline of subsistence level farmers combined with the advent of mechanisation rendered the piantata obsolete. Furthermore, the need for fallow and forage crops declined with both the development of chemical fertilisers and the decline of subsistence farming whose traditional way of raising farm animals to meet domestic needs required either grazing land or the growth of fodder crops. Currently, fodder crops are concentrated only around farms specialising in milk production (Provincia di Venezia 1994b).

[5]For census purposes, population in a comune is classed according to main urban centre, other urban nodes, and across the countryside in scattered homes (ISTAT 1956 & 1994).

Industrialisation and economic transformation also resulted in significant changes to the social and economic organisation of farm production. Table 6.7 provides figures on the evolution of farm ownership characteristics for Noventa di Piave and Eraclea. The categories listed in the first column are drawn from various censuses and imply changes to both social and economic characteristics of farm organisation. In Table 6.7, the most important trend to note is the elimination of the *mezzadria* and tenant[6] farmers by 1990, which signified a move to a modern, and more capitalistic organisation of farm production. In 1930, mezzadria and tenant farmers operated the majority of farms in Noventa di Piave and Eraclea (63.2 and 67.9 percent respectively). They also farmed the majority of land as indicated by the percentage of total hectares under these categories (78.1 and 68.8 percent respectively). Some mezzadria farms still existed in 1970 (the "other" category in the 1970 census included mezzadria farms) (ISTAT 1972a).

Previously, it was mentioned how economic transformation created new non-farm opportunities for the landless farmer. In many cases, non-farm employment of farmers and family members also brought in sufficient income to allow farmers to purchase their own land. By 1990, all farms were classified as being operated either directly by their owners *(conduzione diretta)*, or through use of salaried labour *(conduzione con salariati)*. The numbers in the table clearly illustrate how subsistence agricultural era forms of organisation have been eliminated in favour of owner/operator forms of organisation.

By themselves, the modern ownership categories and numbers do not adequately illustrate the modern organisation of agriculture, as these two categories are traditional census designations based strictly on whether or not hired farm labour is used in the operation. They are now largely obsolete for economic classification of farms. However, the use of salaried labour today

[6]The category of "rented" does not exist in the 1970 and 1990 agricultural censuses and these operations are likely grouped in the "other" category for these two years. As there are no farms listed under "other" in 1990, it is probably safe to assume that tenant farmers no longer exist in either comune by 1990.

Table 6.7
Number of Farms and Area Farmed by Socio-economic System of Operation – Noventa di Piave, Eraclea

Ownership/Operation System as a % of Total Farms and Total Area	Noventa di Piave						Eraclea					
	1930		1970		1990		1930		1970		1990	
	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha
Direct Cultivation by Owner*	33.5	19.7	82.5	43.7	97.9	83.9	28.3	31.2	88.5	26.9	96.3	42.9
Using Salaried Labor**	NA	NA	2.3	24.9	2.1	16.1	NA	NA	4.3	60.3	3.7	57.0
Mezzadria	25.4	58.8	NA	NA	0	0	37.9	52.2	NA	NA	0	0
Rented	37.8	19.3	NA	NA	NA	NA	30	16.6	NA	NA	NA	NA
Other***	3.3	2.2	14.7	31.3	0	0	3.4	0.001	7.2	12.7	0	0
Total Farms & ha Cultivated	421	1686	354	1594.4	333	1273.9	725	7994	1029	9074.5	982	7515.5

*Or *conduzione diretta.*
**Implies larger scale operations relying primarily on salaried labour or *conduzione con salariati.*
***1930 "other" includes mixed ownership operations; 1970 "other" includes mezzadria and rented farms.

Sources: ISTAT 1991a; ISTAT 1972a; Istituto Centrale di Statistica del Regno d'Italia 1935.

generally implies a larger scale and more capitalistic farm enterprise (Provincia di Venezia 1994b). This is somewhat distinct from the "direct cultivation" designation, which today includes family run farms and part time farm operations of varying sizes. In the pre-modern era, the "direct cultivation" designation implied more large-scale capitalistic farm enterprises.

As to the production characteristics of farming enterprises, the nature of the census data limits accurate classification of farms by primary production. Specifically, it is impossible to accurately classify modern farming enterprises by principle farming activity (e.g. cash cropping, vineyards, stock farms), and compare them with the pre-modern era, where there was no designation of farms by activity type. However, some figures are available on the composition of farming in the broader province of Venezia. In 1990, field crops comprised 57.7 percent of the gross value of agricultural production in the province of Venezia, followed by livestock at 26.9 percent, and vineyards/orchards at 15.4 percent (Provincia di Venezia 1994b).

Other details of the modern social and economic organisation of agriculture can be gleaned from further analysis of the censuses and available literature. Table 6.5 illustrates the transformation of agriculture through employment figures. In addition to the exodus of the farm population to other economic activities, there have also been other demographic changes in agriculture. One important change between 1970 and 1982 has been the general ageing of the farm operator population. Most significantly, there has been a substantial fall in the numbers of operators aged 35 to 45, while there has been a substantial increase in the number of operators over 65. This is attributable to younger elements of the farm population seeking better employment opportunities outside the farm (Provincia di Venezia 1994a).

Parallel to social and economic changes in the modern era is the phenomenon of the part-time farmer (Provincia di Venezia 1994a). This phenomenon is characterised by a substantial percentage of principle farm operators being employed outside the farm. In Noventa di Piave and Eraclea respectively, 32.1 and 37.8 percent of farm operators were listed as employed outside the farm in the 1990 census. In the province of Venezia as a whole, 31 percent of farm operators listed their principle employment as being off the farm (ISTAT 1991a). This phenomenon is characteristic of the Veneto in general where the part-time farmer is really a small landowner who supplements family income through cultivation of his land. For census purposes, a farm is defined as an entity rendering, or designated for some type of agricultural production (ISTAT 1991a). This type of activity is possible with the predominance of cash crops, which require only periodic attention. With part-time farming, tilling, planting and harvesting is usually contracted out by small landholders to *contoterzisti* (Provincia di Venezia 1994a). These are contractors or larger landowners possessing necessary machinery to perform these operations.

Other organisational change accompanying social and economic transformation is related to characteristics of farm size. Table 6.8 illustrates evolution of farms by size class of operation. In both 1930 and 1990, the majority of farms in both Noventa di Piave and Eraclea are smaller than five hectares. For all periods, a substantial portion of farms in both comuni are one hectare or less; although the percentage of farms in this category has diminished toward 1990 and is less the case in Eraclea. The overall trend in both comuni has also been toward an increasing number of farms in smaller size categories. In Noventa, the number of farms less than five hectares has increased from 75.3 to 78.9 to 84.6 percent of all farms for each period respectively. For Eraclea, the number of farms in this category has increased from 56.4 to 79.2 to 79.6 percent.

From an area perspective (column 2 under each year), some important trends emerge. First, the total area farmed in both comuni has decreased over time. This is attributable to increases in other land uses, and is part of a larger provincial trend (Provincia di Venezia 1994b). The trend has also been toward smaller classes of farm (less than 5 ha) occupying an increasing proportion of total cultivated area (from 23 to 30.7 percent in Noventa; from 6.6 to 18.6 percent in Eraclea). Smaller farms have also tended to comprise a greater proportion of total agricultural land in Noventa di Piave.

Table 6.8
Number of Farms and Area Farmed by Size Class of Operation – Noventa di Piave, Eraclea

Size Class of Farm	Noventa di Piave						Eraclea					
	1930		1970		1990		1930		1970		1990	
	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha	% of Total Farms	% of Total ha
0 – 1 ha	43.7	4.9	39.8	4.8	37.5	5.0	32.6	1.2	36.8	1.9	21.2	1.8
1 – 3 ha	25.2	11.6	30.8	12.4	47.1	25.7	18.6	3.3	31.8	6.9	58.4	16.8
3 –5 ha	6.4	6.5	8.5	7.2			5.2	2.1	10.6	4.8		
5 – 10 ha	10.9	20.6	9.6	16.0	6.6	11.8	10.5	7.8	6.9	5.7	11.3	10.2
10 – 20 ha	10.9	37.7	8.5	27.5	4.5	15.5	19.4	28.2	7.2	12.6	4.5	7.5
20 – 50 ha	2.8	18.7	1.9	11.8	3.0	23.5	11.4	27.7	3.6	10.5	2.4	9.4
50 –100 ha	0	0	0.8	20.2	1.2	18.4	1.4	9.9	2.6	57.6	0.4	3.9
Over 100 ha	0	0			0	0	0.8	19.8			1.7	50.2
Total Farms & ha Cultivated	421	1686	354	1594.4	333	1273.9	725	7994	1029	9074.5	982	7515.5

Sources: ISTAT 1991a; ISTAT 1972a; Istituto Centrale di Statistica del Regno d'Italia 1935.

Conversely, the proportion of total agricultural land farmed by larger enterprises (over 20 ha) has increased from 1930 to 1990 in both cases (from 18.7 to 41.9 percent in Noventa; from 57.4 to 63.5 percent in Eraclea). This trend is especially more pronounced in Eraclea, where the proportion of land farmed by enterprises over 100 ha has increased from 19.8 to 50.2 percent. In general, average farm sizes are larger in Eraclea (between 10 and 20 ha) than Noventa di Piave (between 5 and 10 ha) (Provincia di Venezia 1994a).

The size class figures in Table 6.8 provide some important clues as to trends in farm organisation. In general, there has been an increasing trend toward both small and large farm enterprises occupying a larger proportion of area under cultivation. This has been at the expense of medium sized farms (5-20ha), whose number and proportional area have declined over time. This dichotomous evolution is noted by the Provincia di Venezia (1994b) as having occurred throughout the province of Venezia. Fragmentation of smaller and medium sized properties occurred in areas with elevated economic development in other sectors. This also parallels the increasing phenomenon of part-time farming, which has also been driven by laws and trends related to the division of property for hereditary purposes (Provincia di Venezia 1994a &1994b). In areas of higher and more diverse economic opportunities, inherited property is more likely to be kept and farmed on a part-time basis rather than sold or liquidated. Conversely, in recently reclaimed areas outside areas of alternative economic opportunities (e.g. Eraclea), there has been a tendency toward accumulating land and increasing farm size in order to gain advantage from economies of scale (Provincia di Venezia 1994b).

Industrialisation and economic development also paved the way for the application of modern agricultural technologies (machinery, pesticides, herbicides, fertilisers and hybrid seeds). These also played a large role in agricultural and landscape change. One important development was the displacement of animal power and human labour with mechanised equipment. For example, the number of tractors in the province of Venezia increased from 600 in 1926-28, to over 16,000 in 1982 (Consiglio ed Ufficio Provinciale dell'Economia di Venezia 1930; ISTAT 1985). This had a large impact on the structure of landscapes as once integral components of the agricultural landscape (ditches, hedgerows) were gradually removed or altered to facilitate the efficient movement of machinery.

Of greatest impact on agriculture, was the availability and widespread heavy use of chemical fertilisers. The heavy application of chemical fertilisers permitted the establishment of cereal crop monocultures and the elimination of the need for traditional cropping patterns designed to maintain fertility. Between 1951 and 1982, the application of chemical fertilisers increased dramatically as is shown in Table 6.9. Correspondingly, crop yields dramatically increased with the assistance of chemical fertilisers combined with hybrid crops, pesticides[7] and herbicides. This is illustrated in Table 6.10.

Table 6.9
Application of Chemical Fertilisers (kg/ha) - Veneto Region

	1952	1970	1982	1952-82 % Change
Nitrogen (N)	10.7	43.6	142	1227%
Phosphorous based (P)	25.5	40.1	86.2	238%
Potassium based (K)	2.4	29.9	84.3	3412%

Sources: ISTAT 1983; ISTAT 1972b; ISTAT 1954.

Table 6.10
Average Crop Yields (kg/ha) - Province of Venezia

	1952	1970	1982	1952-82 % change
Corn	2580	6200	7900	206
Wheat	2980	3840	5400	81
Soybeans	1570	——	3900	148

Sources: ISTAT 1983; ISTAT 1972b; ISTAT 1954.

[7] In Italy overall, the consumption of insecticides grew by 340 percent between 1950 and 1987 (Galante & Sala 1993). Also see ISTAT (1991b) for figures on growth of pesticide and fertiliser use for Italy as a whole.

These trends correspond to general Italian patterns (ISTAT 1991b; Galante & Sala 1993). For example, Galante and Sala report that between 1951 and 1988, the use of potassium (K) based fertiliser increased from 20,000 tons per year to 400,000 thousand tons per year, and the use of phosphates (P) increased from 250,000 to 600,000 tons per year.

In this regard, it can also be stated that modernisation of agriculture has generally decreased the health of landscapes if common health and integrity notions are considered. The simplification of landscapes eliminated landscape structures (hedgerows, ditches) which provided habitat for diverse communities of flora and fauna. The heavy use of agricultural chemicals created environmental externalities, or new levels of human-induced stress, which had not existed in the previous era.

There were important institutional factors which also played a role in the modernisation of agricultural systems. Throughout the 1950's and 1960's, Italian agricultural policy sought to increase production by encouraging the adoption of modern technology. Between 1961 and 1970, two five year "green plans" were passed to promote greater productivity in agriculture and included public grants for the purchase of machinery, fertilisers, chemicals, etc. In the 1970's, a national agricultural plan (*Piano Agricolo Nazionale*) was introduced and had as its focus the issue of self-sufficiency. The emphasis on increasing production and productivity contributed to increased investment in equipment and increased consumption of farm inputs (Galante & Sala 1993).

Another factor, which played a crucial role in land use change, was Italy's membership in the European Community and the Common Agricultural Policy (CAP) officially established in 1962. The CAP was originally conceived to accomplish a number of objectives, including increasing productivity, stabilising markets, and guaranteeing supplies for a Europe which still had the memory of World War II food shortages fresh in its mind. Its main objective was to support farmers by guaranteeing them a fair standard of living through price supports. These were geared to maintain the income of even the least efficient farmers (Gardner 1996).

Essentially, the system worked as follows. A minimum threshold price for agricultural commodities was established in the member states with imports pegged at a higher price. The Community at the set minimum price purchased any surplus production of a commodity, which could not be sold in open markets for at least the threshold price set by the Community. The Community then handed it over to traders who would sell it on international markets. When world or international market prices fell below threshold prices guaranteed to farmers, the Community would have to subsidise traders to sell the commodity on international markets at lower cost.

In effect, the Community was subsidising the farmer without actually paying the farmer by guaranteeing a minimum price while maintaining price stability within the Community through the purchase of any surplus, and its subsidised disposal on the international market. In the long run, this policy had the effect of maintaining high prices for consumers and encouraged production and investment in agriculture. This also created huge surpluses and negative environmental externalities (ESAV 1995; Gardner 1996).

In Italy, this policy had a similar effect on agriculture, especially in more favoured lowland areas. Here it contributed to the formation of highly intensified agricultural systems with heavy investment in agricultural inputs (Galante & Sala 1993). Within the province of Venezia, the CAP was one of the main factors (along with modernisation/technology and economic rationalisation) that encouraged the expansion of cereal and industrial (e.g. sugar beets, soybean) crop monocultures at the expense of forage crops, vineyards and orchards (Provincia di Venezia 1994b).

In the 1980's however, Italian agriculture faced the increasing problem of worsening output/input ratios (Galante & Sala 1993), and stagnating growth. Final agricultural output in

1993 was only one half a percentage point higher than in 1983[8] (Eurostat 1995). Within the Veneto region, agriculture experienced slower per capita income growth relative to other sectors. For example, between 1986 and 1990, per capita gross income of agriculture grew only 19.6 percent compared to 72.5 and 80.6 percent growth in the industrial and tertiary sectors respectively[9] (Provincia di Venezia 1994b).

In 1992, the European Union instituted an agricultural reform package designed to mitigate severe market distortions, huge agricultural surpluses and negative environmental externalities (e.g. surface and groundwater pollution, soil degradation) arising from the old CAP. The principal measures, to be phased in during 1993-96, include:

- *A substantial reduction in cereal prices in order to redress their loss of competitiveness for use as animal feed relative to other competing products;*
- *Measures to manage supply such as "set aside" or removal of agricultural land from production;*
- *The introduction of an ambitious agri-environmental programme involving aid to encourage farmers to adopt less-polluting and more environmentally sensitive methods of production as well as aid for countryside preservation and the conservation of natural resources;*
- *Direct monetary payments to farmers to compensate for lost income arising from lower cereal prices, set-aside practices, and more extensive methods of production;*
- *The introduction of financial incentives for farmers who agree to whole or partial afforestation of their land (Commission of the European Communities 1993).*

Despite these reforms, European agriculture has retained its highly subsidised nature. The main difference between the old policy and the new is the movement to direct subsidisation of farmers and financial incentives to move farmers to adopt the practices encouraged by the new policy. It should also be noted that policy reviews and subsidy changes are ongoing and the preceding paragraphs are intended to only provide a general overview of the effects of the CAP on agriculture.

The new policy does, however, contain some important and relevant goals with respect to promoting sustainable agriculture. The 1992 reforms introduced measures designed to eliminate

[8]Figures are unadjusted for inflation.

[9]Figures are unadjusted for inflation.

the negative environmental externalities arising from excessive production, and general practices of conventional agriculture (Reg. 2078/92). Specific actions to be promoted include:

- *substantial reduction of chemical fertilizers (at least 20 percent of normal applications), pesticides and herbicides;*
- *the introduction of organic/biological agriculture;*
- *reduction in cereal crop production and long term conversion of cropland to pasture/forage crop "set aside";*
- *change to more extensive forms of crop and livestock production, and reduction of livestock density;*
- *replanting of hedgerows and reforestation of agricultural land;*
- *upkeep of abandoned land;*
- *land management for public access and leisure activities.*

These environmental measures are to be incorporated into the national legislation of member states and promoted through the compensation of lost income to farmers who voluntarily abide by one or more of the requirements and their related norms. A schedule of technical regulations/norms and compensation has been drawn up and farmers must agree to participate for a minimum period of 5 years (Commission of the European Communities 1993; ESAV 1995).

Concerning biological agriculture, European legislation introduced in 1991 (Reg. 2092/91) defined the practice and permitted methods of production based on norms established by European biological agricultural movements[10]. In Italy, the responsibility for regulating biological agriculture was subsequently delegated to private organisations that would conduct periodic inspections and product chemical analysis to ensure compliance with norms. Compliance is seen as important by biological agricultural movements given widespread use of the term by cultivators who do not strictly adhere to the basic principle of no chemical inputs (Carrer 1993; Bustaffa & Soldati 1995). It is also worth noting that although the Italian government allocated funds for the promotion of biological agriculture in 1991, European legislation does not specifically target

[10]Political lobbying by the dominant European and Italian biological agricultural organisations (International Federation of Organics Agricultural Movements - INFOAM, and *Associazione Italiana per l'Agricoltura Biologica* - AIAB) was a major factor in the adoption of this legislation.

compensation to biological farms (Carrer 1993). Biological farms are only eligible for compensation based on the general agricultural reforms.

2. Assessment of Agricultural Systems

The landscape analysis from Chapter 5 combined with the preceding analysis suggest a "conventional" form of agriculture has evolved over the last 30 years in the Veneto Region and Lower Piave area. This is based primarily on cereal crop monocultures relying heavily on technological inputs of fossil fuel energy, chemical fertilisers, pesticides and herbicides. This conclusion is confirmed by key literature sources (Galante & Sala 1993; Provincia di Venezia 1994b; Bustaffa & Soldati 1995), as well as by visual ground level inspections of the Lower Piave. This form of agriculture is radically different from the previous era's subsistence form, which consumed few external (to the system) inputs and persisted until the 1950's. The transformation of agriculture did however result in huge increases in productivity, even if at the expense of heavy energy and chemical inputs.

Table 6.11 provides a summary comparison of the "health" and "sustainability" aspects of both agricultural systems. From a farming system standpoint, the relatively less productive pre-modern subsistence system was much more ecologically sustainable in the short and long term. In this regard, it was a true sustainable system as it functioned without, or with a minimum of, external chemical inputs, which are so common today. Farming systems also closely approximated what has been referred to as "biological" agriculture (Carrer 1993; Bustaffa & Soldati 1995). Current farming systems rely heavily on external chemical and technological inputs.

From a landscape ecological point of view, earlier farming systems were also much more conducive to biophysical "health". This was due to the presence of hedgerows, vegetation, and the high degree of land use and crop diversity. These characteristics were identified in

Table 6.11
Health and Sustainability Comparisons of Modern and Pre-Modern Agricultural Systems

Considerations:	Pre-Modern Era	Modern Era
Farming Systems:		
1. Farming system characteristics	-predominantly mixed farming subsistence agricultural system; larger salaried operations also emphasising mixed farming	-dominated by conventional cash crop monoculture farming systems
2. Farming Methods	-labour intensive and reliance on animal power -"biological" farming techniques used to maintain soil fertility and production **-farming system sustainable in the short and long term** given absence of external subsidies	-entirely mechanised with high chemical and energy inputs **-unsustainable without these technological inputs/subsidies** -no farms in Lower Piave listed as employing "biological" farming methods[11].
Landscape/ecological		
1. Vegetation	-presence of an abundant and diverse vegetation regime in the form of hedgerows and piantata	-open fields almost totally devoid of arboreal vegetation
2. Diversity	**-high degree of land use diversity and crop diversity** due to mixed farming regime -moderate level of landscape diversity (e.g. presence of piantata, closed fields and some terrestrial natural areas (wetlands) -abundant vegetation conducive to biological diversity	**-low level of landscape diversity** due to emphasis of cereal crop monocultures -"green deserts" due to almost total removal of hedgerows and vegetation
3. Risk factors (or human-induced stress)	-mostly related to landscape governance (e.g. periodic cutting of vegetation, drainage works, excavating of water courses) **-stress easily absorbed by landscape system**	-arising from chemicalisation of agriculture, urbanisation, and industrial activities -include excessive runoff of nutrients, bioaccumulation of toxic contaminants, eutrophication of waterways, contamination of groundwater **-stress not easily absorbed or dissipated by landscape system**

[11]Information based on Italian Biological Agricultural Organisations as reported in Carrer (1993).

Economic: 1. Macroeconomic Viability	-relatively low productivity and economic viability compared to modern era; **-existing macro economy sustainable in the long term** because of the predominantly subsistence nature of agricultural economy	-highly profitable economic sector in terms of larger economy; sectoral growth tending to stagnate, however, over the last few years -overall, **sector appears to be economically viable** depite current stagnation; this should also be the case even with the adoption of more sustainable agricultural techniques in future - see example from Bustaffa & Soldati (1995)
2. Microeconomic Viability	**-very low farm productivity** and economic profitability compared to modern era; **-individual farms sustainable in the long term** given the self-sufficient nature of subsistence farming	-apparant **high productivity and profitability** of individual farms. Due in large part to modern technological and chemical inputs. EU subsidies may also play an important role **-long term sustainability questionable** without external subsidies

Chapter 2 as being favourable to the maintenance of biological diversity[12], which is a key condition of ecological integrity[13]. Furthermore, most modern-day ecological stresses and environmental externalities arising from modern agricultural practices were non-existent in the earlier era.

Some economic comparisons are also included on Table 6.11. However, these are strictly general assessments deduced from some of the previously noted trends related to modern agriculture, combined with general knowledge of the level of economic development existing in the previous era. A proper assessment of economic aspects of sustainability would require additional data, followed by detailed empirical analysis of inputs vs. outputs in both eras. Nonetheless, the level of development in the existing agricultural economy compared to the subsistence era suggests that the modern form of agriculture is much more productive and profitable from a conventional economic perspective. However, this is largely sustained by

[12] Refer to the discussion centering on Tables 2.5 and 2.7 in Chapter 2.

[13] Refer to the discussion on ecological integrity in Chapter 2.

external chemical inputs/subsidies given the characteristics of modern agriculture. EU monetary subsidies also likely play an important, but undetermined, role in the high economic productivity of modern agriculture.

Omitted from this analysis are social considerations of health and sustainability related to agriculture. This aspect has been excluded for reasons extending from those cited in section 1.3 of Chapter 1. This is also a complex issue because it relates to the sustainability of communities as well. Nonetheless, it is safe to say that overall social conditions related to the rural/agricultural population have vastly improved in the modern era. The repressive agricultural property and productive relations, combined with limited economic development and opportunities in other economic sectors, kept the vast majority of the rural population living at bare subsistence. Thus, notwithstanding better conditions of biophysical health and sustainability, the previous era is largely unlamented, from a social and economic point of view, by those alive today who have experienced it.

6.3 SURFACE WATER DRAINAGE

This part of the analysis examines surface water drainage characteristics and conditions of the Lower Piave and their parallel evolution with landscape change. The objective of this analysis is to examine: current drainage conditions; their evolution over time; the linkages between land drainage and other landscape components; and the effects of landscape changes on surface water flow and drainage. Given how water plays a vital and dominant role in reclaimed landscapes, as well as being linked to other landscape elements, this analysis is a vital to the entire issue of landscape health in the Lower Piave.

I. Existing Drainage System and Flood Risk

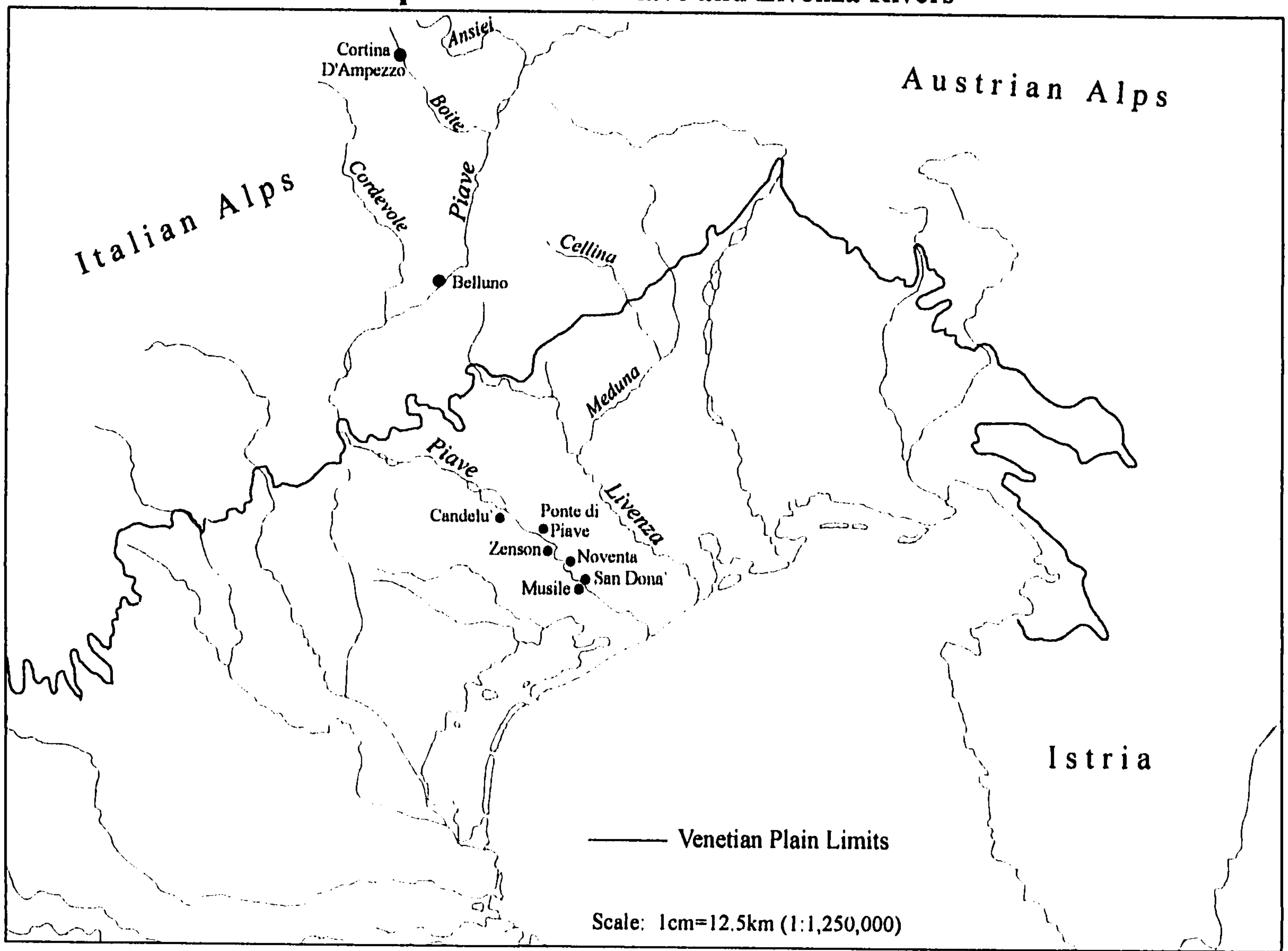
Within the Lower Piave, there are essentially two significant characteristics regarding surface water drainage that need to be considered. One is the drainage of the two major rivers in the area: the Piave and Livenza. The other is the drainage of reclaimed territory between these two rivers. In terms of land drainage, the defining characteristic of the territory between the two rivers is an internal watershed, which relies on mechanical pumping stations for its drainage. These two hydraulic elements are essentially separate and non-interacting given no pumping stations discharge directly into the Piave River (Consorzio di Bonifica Basso Piave 1991; Provincia di Venezia 1993). The exception to this occurs during periodic flood events when the Piave and Livenza Rivers have been known to overflow into the surrounding lowland areas. The full extents of the Piave and Livenza rivers are illustrated on Map 6.2.

The Piave river originates in the Italian Alps and crosses the upper and mid-elevation portions of the Northern Italian Plain as a "braided" fast-moving river. When it reaches the lower plain and near coastal area, it begins a slow meander before its drainage into the Adriatic Sea. Along the lower 15-20 km of the river, from the town of *Musile di Piave*, the meanders have been eliminated given this portion of the river channel is actually a diversion from its original path.

Until the 16th century, the Piave ran adjacent to the Venice Lagoon (or along the fringes of the lagoon) before draining into the Adriatic (Map 3.5). A permanent channel was then created by the construction of a dike between the river and the lagoon *(Argine San Marco)*. This was designed to prevent the river from overflowing into the lagoon during frequent flooding. (Zanetti 1995a). Starting in 1565, the Venetian Republic diverted the lower course of the Piave river away from the Lagoon by carving out a channel in adjacent marsh areas to the northeast (Zanetti 1995a). A dike was also constructed along the newer river channel to contain frequent high water levels and flooding which plagued the low portions of the Northern Italian Plain.

The diversion and diking of the Piave removed natural meanders that are characteristic of

Map 6.2: Extent of Piave and Livenza Rivers



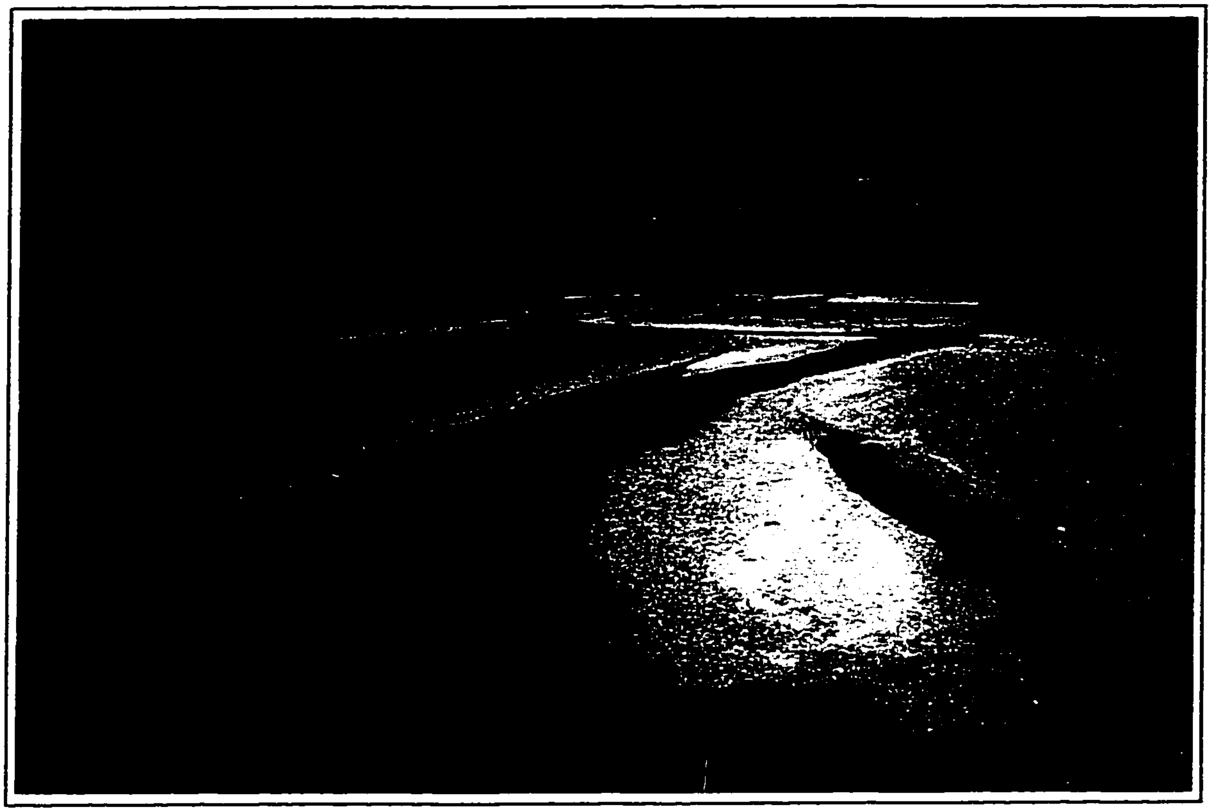
Base map reproduced from Touring Club Italiano (1986)

slow moving rivers. The elimination of meanders resulted in some undesired consequences. Namely, sediment once deposited along adjacent shores was now deposited on the riverbed causing the riverbed to gradually rise. Over the years this necessitated frequent and laborious dike build-up and maintenance. Furthermore, channelling and diking were accompanied by reclamation of adjacent lands for agriculture (using *colmata* methods). The elimination of the water absorbing flood plain along with reclamation (and settlement) created hazardous conditions for humans given frequent flooding and the danger of water overflowing, or collapsing a dike.

The Piave river runs for a total length of 220 km and drains a land area of 3800 square kilometres - 70 percent of which is 900 metres above sea level. The lowland portion of the river equals 64 kilometres in length. Geomorphologically, the riverbed in the lowland portion of the river can be divided into two distinct sections. In the upper plain, before it reaches *Ponte di Piave*, the riverbed is wide and braided in nature, and underlain by various sizes of sands, gravels and stones (Figure 6.2). The withdrawal of water along the upper reaches of the plain for irrigation has drastically reduced the flow of water resulting in reduced widths and depths of the river's channels along this portion. The riverbed south of Ponte di Piave retains a trapezoidal shape and is enclosed by dikes until it reaches the Adriatic. Average depth of the river in this tract is 5 metres, with wide variations as some depths exceed 10 metres due to erosion and extraction of sand and gravel. In this tract, river sediments are composed of sands and silts with occasional sections of gravel overlaying the sandy beds towards the upper plain (Zanetti 1995a; Zaggia *et al.* 1996).

For the most part, the river retains characteristics of a *torrente* (or torrent), meaning its flow is highly variable according to season. Peak flows occur in spring and fall during periods of intense precipitation. Peak flows during May and June are augmented by the melting of mountain snows. Conversely, water levels are low during summer and winter. As the river enters the upper plain, it has an average annual flow of about 80 cubic metres per second. With the subsequent

Figure 6.2
"Braided" Piave Riverbed Above *Ponte di Piave*

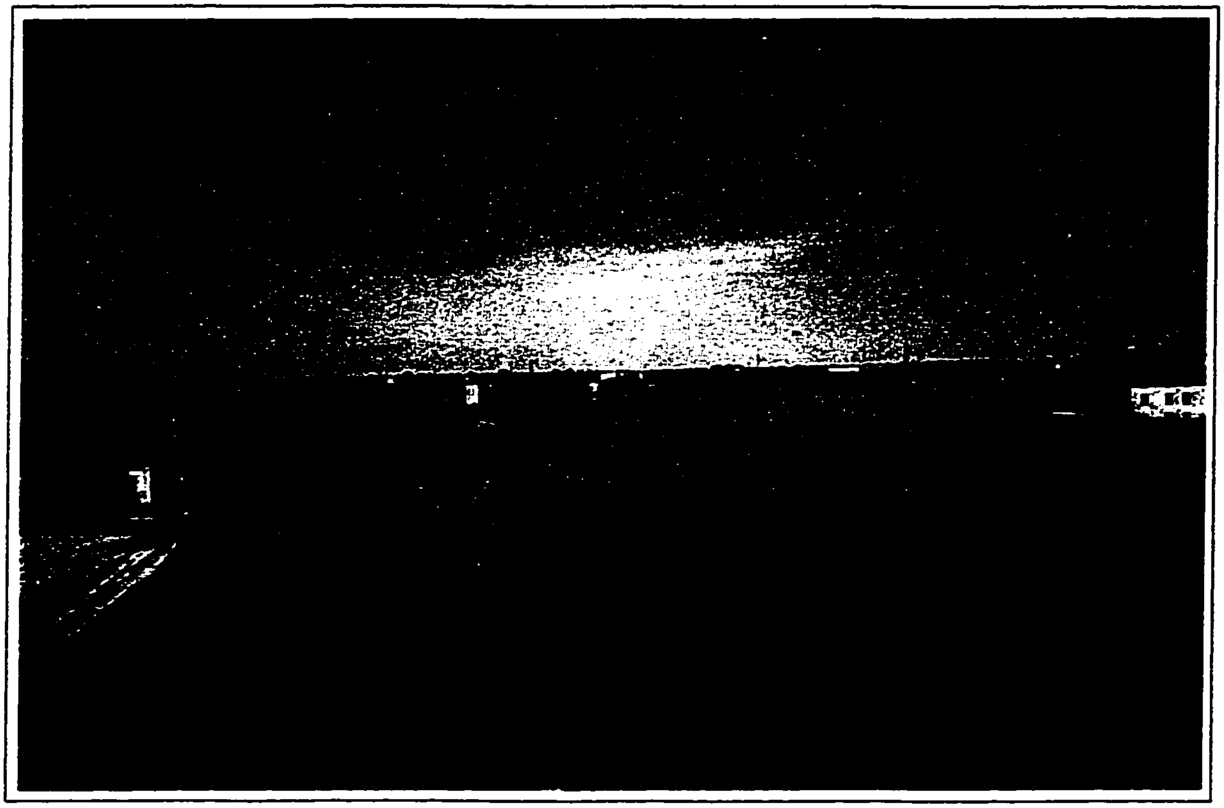


extraction of water for irrigation along the middle part of the plain, average annual flow is reduced to an estimated 30 cubic metres per second. However, a peak flow of 4825 cubic metres per second was recorded along the upper plain portion of the river during the last great flood event in 1966. This figure is significant regarding flood hazards because the dikes lining the lower portion of the river are built to withstand a maximum flow of 3000 cubic metres per second. The 1966 flood was catastrophic and resulted in widespread inundation of lowland areas and resulting property damage. Thus flood hazards associated with the flow of the Piave river are ever present for Lower Piave area inhabitants (Provincia di Venezia 1993; Zanetti 1995a; Zaggia *et al.* 1996).

The characteristics of the Livenza river are substantially different from those of the Piave river and others in the northeastern Italian area. The Livenza river originates in the *Prealpi* area of the Northern Italian Plain, where the river is fed by springs arising from the existing karst region, and extends 111 kilometres to the Adriatic Sea. The remainder of the river's flow is provided by its two main tributaries; the *Meduna* and the *Cellina* which originate in Alpine areas. Both have characteristics of a torrent, including the characteristic braiding. Apart from its tributaries, the Livenza river meanders along almost its entire route to the Adriatic and is contained by dikes as well (Ghetti 1968; Provincia di Venezia 1993). Also, the mouth of the Livenza river (Figure 6.3) has undergone numerous changes and diversions since Roman times; although records of its diversions are vague compared to the Piave river.

Concerning flow and associated flood risk, the spring-fed nature of the Livenza means a much more regular flow with only a minor difference between the maximum and minimum flow. Also, there is more of a lag time between high precipitation events and maximum flow. The peak flow of the Livenza has been estimated at 1800 cubic metres per second (Fassetta 1977). Unfortunately, records of Livenza river's flow are insufficient to draw accurate conclusions regarding average flow compared to other Veneto region rivers, which have been monitored for longer periods of time. Nonetheless, within the 1935-49 period, an average daily flow of 52.25

Figure 6.3
Lower Reaches of Piave and Livenza Rivers



Top Photo: Mouth of Piave River
Bottom Photo: Near Mouth of Livenza River

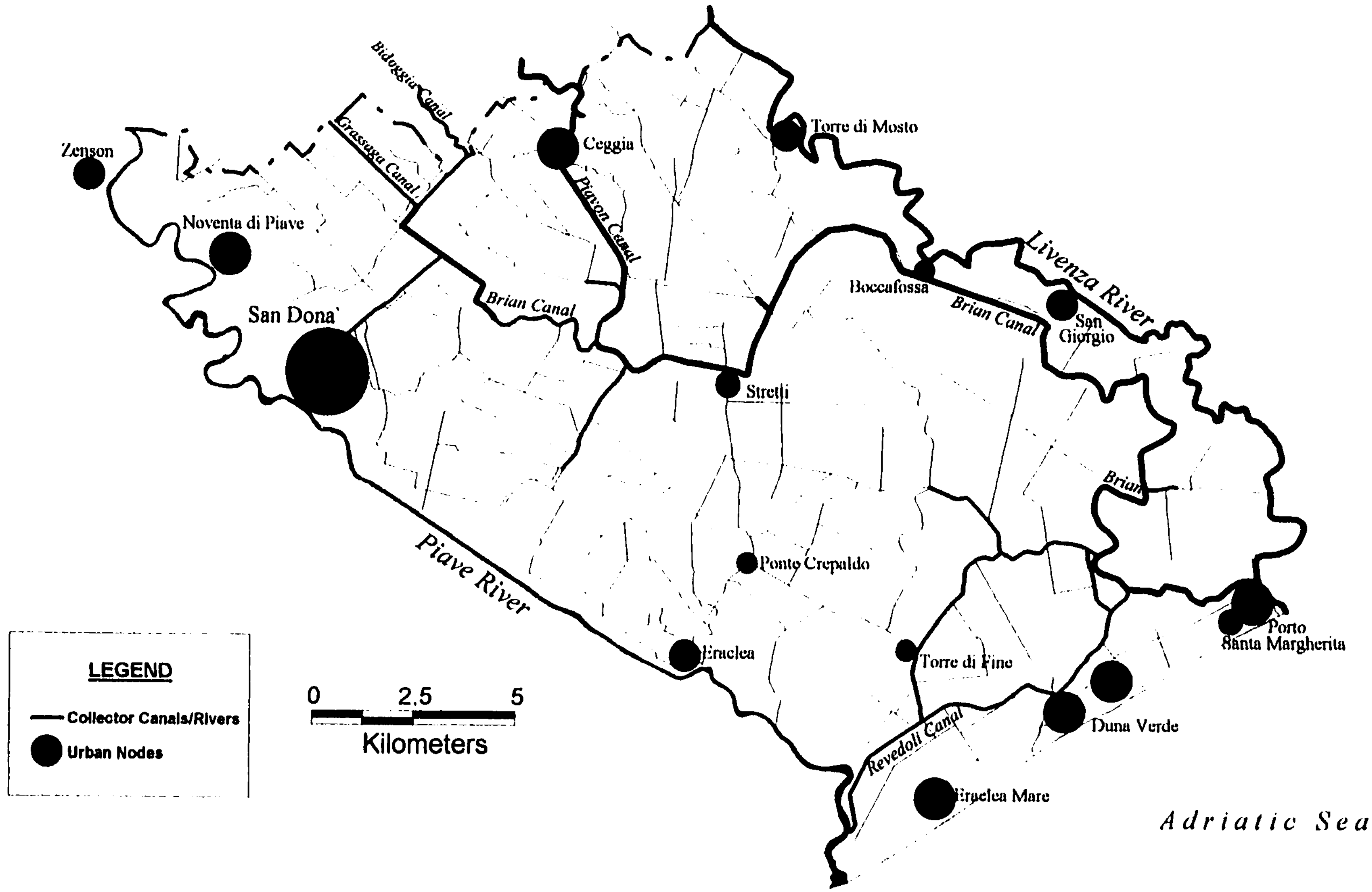
cubic metres per second was recorded (Provincia di Venezia 1993). This situation is substantially different from that of the Piave, which is fed primarily from mountain runoff and has a peak flow of almost double the volume. In comparison to the Piave, only 34 percent of the 2088 square kilometre *Meduna-Cellina-Livenza* basin is located in alpine areas. Thus, the river presents much less flood risk to inhabitants of adjacent areas given reduced quantities of water carried during flood events.

In terms of overall flood risk, the Lower Piave area is at risk to some degree of flooding every 5 to 10 years, with the exception of the small portion above the centre of Noventa di Piave, which is the highest elevated area in the Lower Piave. In this case, the 5-10 year figure represents the average frequency of a flood occurrence. That is, over a 100-year period there would be on average 10 to 20 flood events recorded. This figure does not, however, refer to the magnitude or severity of the flood, which can range from flooding of low lying fields, to catastrophic inundation of large areas such as what occurred in 1966 (Provincia di Venezia 1993).

With the exception of the sections of the northern fringe, the lands between the Piave and Livenza rivers are almost entirely systematically drained by a series of canals and pumping stations given that almost the entire area is at or below sea level. Map 6.3 illustrates the grid of canals which drain the area. Pumping stations are illustrated on Map 3.2. The existing drainage system can be compared to the pre-reclamation drainage system included on Map 3.6, which was primarily designed to facilitate drainage of the existing marshes in order to reduce hydraulic risk for the few farms and inhabitants. Notably, no canals drain into the adjacent Piave and Livenza rivers because of their elevated beds and high dikes. These were constructed prior to reclamation, thus making it difficult to connect the internal drainage system to adjacent rivers (Provincia di Venezia 1993). This characteristic is demonstrated in Figure 6.3 (lower picture), where the farm building to the right of the river is slightly below water level.

The principal collector canal within the basin is the Brian Canal (or *Scolo Brian*). This

Map 6.3: Existing Drainage Grid and Urban Nodes



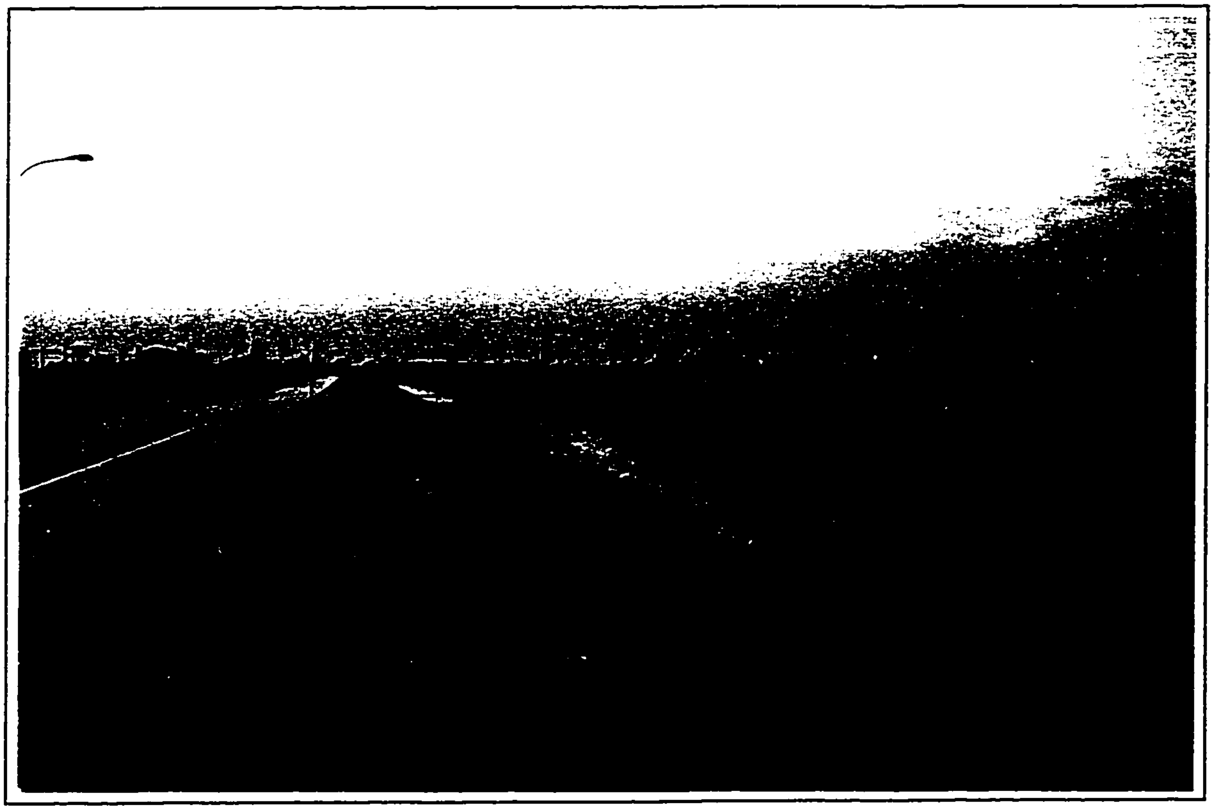
Source: Regione del Veneto, Carta Tecnica Regionale - 1:10,000 series topographic maps canal is navigable along almost its entire length and empties into the Adriatic at the mouth of the Piave river (Map 6.3). The waters of this canal originate in the upper Venetian plain from the *Bidoggia*, *Grassaga* and *Piavon* canal/river systems. It is fed further within reclaimed areas by a series of collector canals, which in turn are fed by an intricate grid of collector ditches and field ditches spaced every 25-40 metres or so on every farm field. Figures 6.4 and 6.5 provide some illustration of the existing drainage grid. Figure 6.4 shows an aerial view of the Brian Canal being joined by two smaller canals near the village of *Cittanova*. Figure 6.5 shows the Grassaga canal which originates from original Roman centuriation.

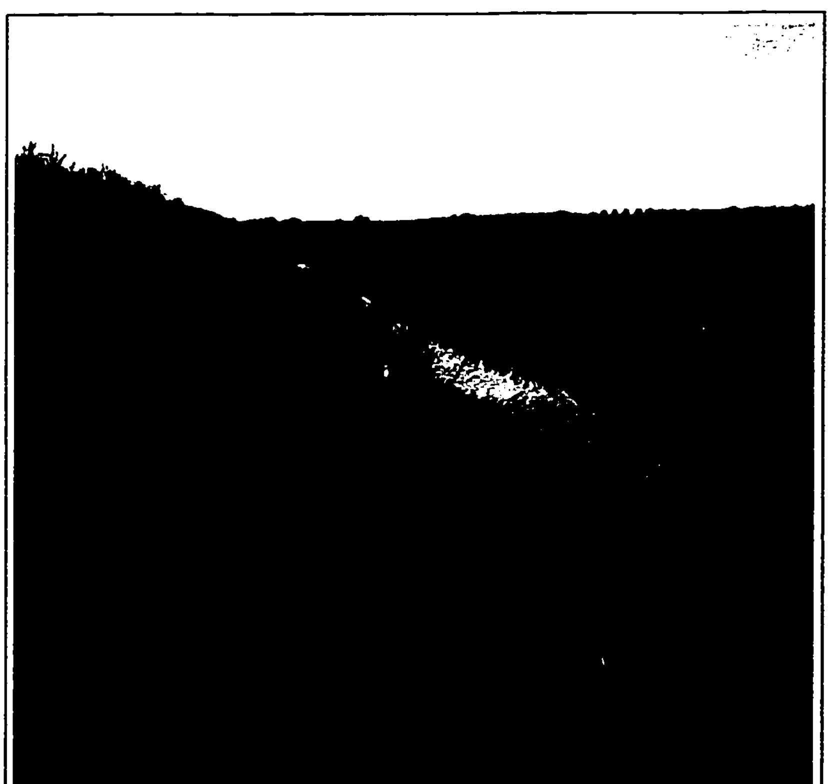
2. Key Issues Concerning Land Drainage

Given the peculiar drainage characteristics of the Lower Piave area, a number of key issues related to land governance have been identified. **The most important aspect of land governance has been identified as the intricate system of drains, canals, and pumping stations needed to maintain a 1-2 metre difference between the land surface and the water table** (Fassetta 1977). This is of utmost importance given most of the area is below sea level and would be underwater without the existing infrastructure. Thus the entire system of habitation and agriculture depends on the ability to govern land drainage, including the integrity of drainage infrastructure.

This leads to the second key issue, which relates to the condition of drainage infrastructure. In addition to living with flood risk, the condition of drainage infrastructure is cause for concern to local interests because existing pumping stations and equipment are old and in need of replacement (Consorzio di Bonifica Basso Piave 1991; Provincia di Venezia 1993). While there has been periodic upgrading and addition of new pumps, most pumping stations still rely heavily on the same electric and diesel pumps and motors installed during their original construction early in the century (Fassetta 1977). Spare parts are also difficult to come by for

Figure 6.5
Collector Canals





Top photo: Grassaga Canal along original Lower Piave centuriation cardine
Bottom photo: Basin collector ditch/canal

motors which are no longer being manufactured.

In addition to the problem of ageing pumping equipment, there is the problem of the state of the canals. Over time, canals lose their trapezoidal shape (and capacity) as they fill in with sediment. This problem is compounded by frequent slope failures along canal banks, which also require quick and expensive repair (Consorzio di Bonifica Basso Piave 1991). It has been estimated that to keep maintenance and restructuring costs under control, canals and drainage basins must be excavated and restructured every 50 years. Currently, over 60 years have passed without any major restructuring (Provincia di Venezia 1992).

These three issues indicate quite vividly why this particular reclaimed landscape is referred to as a *highly governed landscape*. In addition to the act of reclaiming marshland to make it suitable for settlement and agriculture, there is the requirement for continued human governance of a highly technological nature. Essentially, once the commitment to reclaim land has been made, infrastructure has to be maintained indefinitely to protect settlements and property.

Another important issue regarding drainage infrastructure is the capacity to pump water from the basin. This capacity has had to be periodically upgraded since initial reclamation. This is attributable to a number of factors, but is especially linked to landscape change factors which were documented in the previous chapter. The evolution of pumping capacity since initial reclamation is the focus of the analysis in the next section. On its own, pumping capacity is an important indicator of the state of the drainage system in the internal watershed. However, because it is strongly linked to other landscape variables, pumping capacity and drainage is also an important consideration when examining the whole issue of highly governed landscapes and biophysical landscape health.[14]

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[14] The Piave and Livenza rivers are excluded from consideration as a major issue because they are disconnected from adjacent reclaimed areas and are not linked to them except with respect to the issue of flood risk. A temporal analysis of these two rivers is also limited by the lack of data regarding such things as flow. This issue is further complicated by the fact that 20th century hydroelectric dams (in Alpine areas) and irrigation projects have altered the flow and sediment transport patterns of both rivers.

3. Landscape Transformation and Pumping Capacity Changes

Figure 6.6 graphically depicts the evolution of pumping capacity through the illustration of *udometric coefficients* for each of the major basins found in the Lower Piave area and their variations through time. Udometric coefficients are coefficients of basin runoff expressed in litres per second per hectare (l/sec/ha), and are calculations that have been used to determine the pumping capacity needed by each basin and pumping station. Within the Lower Piave area there are 15 pumping stations which drain parts of 9 drainage basins[15] (Map 3.2). Five basins that fall within the Lower Piave are listed on the table including: ***Cirgogno***; ***Bella Madonna*** *(Fossa*, *Staffolo and Livenza)*; ***Ongaro Superiore***; and ***Ongaro Inferiore***. A similarly reclaimed basin (***Cavazuccherina***) adjacent to these has been included in the table to reinforce hydrological trends related to reclaimed areas.

On Figure 6.6, one should note the constant upward movement in the graph indicating a trend toward the increase in pumping infrastructure capacity. Essentially, pumping capacity was periodically increased in order to handle precipitation and drainage water from upstream sources, which accumulated in the internal basin. One should also note a particular pattern with most basins where increases are followed by plateaus. More importantly, the pattern of increases tends to correspond to particular time periods. **This is significant because increases can be tied to particular developments including landscape transformations, given that the total amount of water entering the system would not otherwise have increased over the 80-90 years of reclamation.**[16] Each development regarding pumping capacity increases is now reviewed.

In the cases of *Ongaro Superiore, Ongaro Inferiore, Bella Madonna Staffolo*, and *Cavazuccherina*, there was a subsequent increment(s) in the decades following reclamation until

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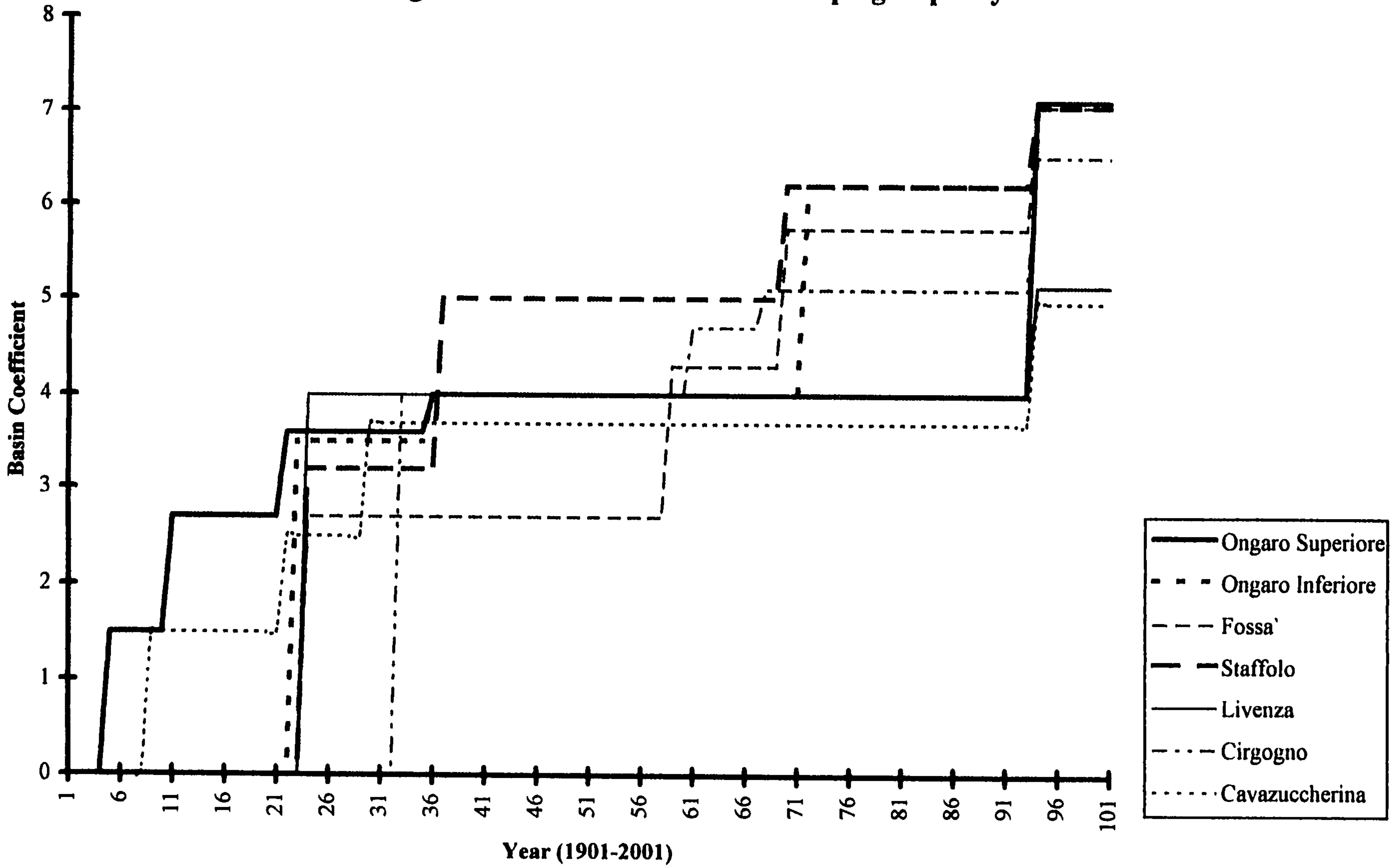
[15] Or individual "*Consorzi*" within the broader *Consorzio di Bonifica Basso Piave*.

[16] If anything, the potential amount of water that entered the system would have decreased over the century given increasingly heavy demands from irrigation, industrial and domestic uses.

Figure 6.6: Evolution of Basin Pumping Capacity



Sources: Fassetta 1977; Consorzio di Bonifica Basso Piave 1991.

the mid 1930's. According to the *Consorzio Basso Piave*, these initial increases in capacity were attributable to initial errors in calculations regarding the predicted maximum flows arising from precipitation events, soil and substrate compaction[17], and expansion of reclaimed areas. Over the longer term, factors such as subsidence and sea level rise[18] also contributed to the need to expand capacity (Fassetta 1977). Pumping capacities then remained stationary in all cases for almost two decades from the mid 1930's to the mid 1950's.

In the late 1950's there was an increase in the *Bella Madonna Fossa*` and *Cirgogno* basins. By the late 1960's and early 1970's, there was another increment(s) in 4 of the basins. The Consorzio Basso Piave has widely attributed these increases to long term factors such as subsidence and sea level rises, combined with the experience of the great flood and sea storm surges of 1966 which inundated much of the Lower Piave area (Fassetta 1977). The great flood of 1966 was the most severe recorded this century in terms of property damage and area inundated. The experience of the flood indicated that much of the infrastructure could not even handle a minor flood, much less a flood of this magnitude. In addition to infrastructure improvements in reclaimed areas, the damage from sea storm surges resulted in the wholesale armouring of the northeastern Veneto coastline through the construction of breakwalls and jetties. This included the entire armouring of the coastline between the Piave and Livenza rivers.

Notably landscape transformations are not mentioned as a cause of drainage change/problems within official Consorzio Basso Piave literature. In this view, this is a glaring omission because the plateau following original capacity increases corresponds to the period of the great agricultural and landscape transformation of the 1950's and 1960's, where fields were

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[17]Within the substrates of former marsh areas are found thin layers of organic material created by the marsh environment. With time and the elimination of the marshes, these layers were expected to oxidise and compact. This phenomenon would have to be accounted for when designing and constructing the drainage system (Fassetta 1977).

[18]Sea levels relative to the surface level of reclaimed areas have been rising at rate of 2-3 mm per year (Fassetta 1977). This figure does not include sea level rise expected or occurring as a result of global warming.

restructured. After this occurred, there was a subsequent increase in pumping capacity. The effect of vegetation on hydrological and hydraulic fluxes is widely known in the landscape ecological field and will be examined further in the vegetation analysis following this chapter. **Given this knowledge, it can be said that the wholesale elimination of vegetation from landscapes in the modern era undoubtedly had impacts on basin drainage and water flows** (the significance of which is discussed later in the chapter). It is unknown whether this omission is by design or by virtue of the lack of an "ecological" culture within the Consorzio. It is well known, however, that agricultural interests are prominent within the Consorzio. This likely means a reluctance to acknowledge that modern era land transformation has impacted drainage.

The last increases in Figure 6.6 are indicative of the capacity recommended as part of the general plan for improvements to the Consorzio Basso Piave proposed in 1991.[19] The last increases for the ***Bella Madonna*** basins should, however, be viewed with caution given that *Bella Madonna Fossa*` and *Staffolo* basins are proposed to be combined under the new plan. Therefore comparisons to previous periods may not be valid. Furthermore, the *Ongaro Inferiore* basin is to be enlarged to 16,400 ha (from 12,240 ha) by incorporating the *Assicurazioni Generali* basin and taking a part of the *Bella Madonna* basin. Enlargement of the *Ongaro Inferiore* basin will actually mean a lower basin coefficient as coefficients have an inverse relationship to the size of drainage basin (Consorzio di Bonifica Basso Piave 1991). Therefore even in this case, comparisons are difficult to make. However, in the adjacent *Cavazuccherina* basin (Map 3.2),

[19] Also known as the ***Piano Generale di Bonifica e di Tutela del Territorio Rurale***. The General Plan was drawn up by the *Consorzio Basso Piave* under a Regional law instituted in 1976 which re-organised the administration of reclaimed areas. The new law required *Consorzi* to submit plans for land and infrastructure improvements in response to the periodic need to rehabilitate and upgrade drainage infrastructure (Provincia di Venezia 1994a). Plans drawn up by the Consorzio are then released for public comment and further changes may be subsequently made. The plans are then sent to the Region (Veneto) for technical review and may be subject to further modification. The final plans are then sent to Regional Council for final approval where a law is then passed declaring the plans in force.

The 1991 Plan proposes: upgrading of pumping stations to replace old equipment and increase pumping capacity; reorganisation of some drainage basins to facilitate drainage; and restructuring and dredging of canals to increase drainage capacity (Consorzio di Bonifica Basso Piave 1991).

where no area restructuring is proposed, the pumping capacity has also been deemed inadequate and is proposed to be upgraded to meet a basin coefficient of 4.96 l/s/ha (from 3.5 l/s/ha).

With respect to proposed infrastructural changes, the Consorzio Basso Piave has identified two key problems/issues that have substantially increased peak run-off and compounded the need for drainage infrastructure improvements[20]. These include increased urbanisation[21], which has increased runoff, and the installation of subterranean drainage systems (Consorzio di Bonifica Basso Piave 1991).

The installation of subterranean drainage systems in the Lower Piave area has accelerated in the last 15 years and represents a double-edged issue with respect to its impacts. It is estimated that 10 percent of total agricultural land in the Consorzio Basso Piave is drained this way (Consorzio di Bonifica Basso Piave 1991). Subterranean drainage consists of the installation of 60-80 mm diameter plastic drain pipes buried 70 to 100 cm below ground level, and spaced every 10-15 metres. It is designed to replace surface drainage ditches. The cost of installation has been estimated at 2 to 3 million lira per hectare[22] (D'Alpaos 1991; Carrer 1993). From an agricultural efficiency perspective, this system is deemed to hold a number of advantages. These include: faster and more even drainage of farm fields, thus allowing cultivation to proceed relatively soon after heavy rains; expansion of field size through the elimination of ditches; easier movement of farm machinery; elimination of the need to excavate ditches every few years; reduction in fertiliser runoff; and reduction in the spread of weeds originating in ditches (Carrer 1993).

Conversely, the negative impacts of subterranean drainage on the overall land drainage have been confirmed by a study conducted by the University of Padua (D'Alpaos 1991).

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[20] From a flood risk perspective, the crux of the present hydraulic problem in the Lower Piave is that the drainage system is can now only handle inundations of five-year frequency. The immediate result of this inadequacy is frequent flooding of fields after heavy precipitation events, and obviously, the inability to handle larger floods. The proposed improvements and modifications will enable the infrastructure to handle minor floods of 10-year frequency (Consorzio di Bonifica Basso Piave 1991; Provincia di Venezia 1993).

[21] From 1910 to 1980, urban area has increased from 0.8 percent to 5.8 percent of total area (Table 5.1).

[22] About 1800-2700 dollars based on current exchange rates (1000 lira = $0.9).

D'Alpaos' study examined runoff from two similar sized parcels of land in the Lower Piave area. One parcel was drained using ditches spaced every 30 metres while the other was drained using subterranean pipes spaced every 10-15 metres at a depth of 1 metre. Runoff was monitored during moderate (up to 4 mm per hour) precipitation events of February 1987 at stations where runoff from the basins was discharged to collector canals. It was discovered that during, and immediately following, precipitation events, the flow of water (in litres/second/ha) from the field with subterranean drains was up to **double** that of the field drained using traditional ditches.

D'Alpaos' study shows how the system using drainage ditches slows the runoff of water, thus moderating peak flows having to be handled by pumping stations. Therefore, the systematic increase in subterranean drainage across large areas will have the effect of producing higher peak flows following even moderate precipitation events. This will further contribute to the need for increases in pumping capacity as proposed by the 1991 *Piano di Bonifica*.

4. Summary and Significance of Land Drainage Trends

The previous section illustrated surface drainage changes using runoff coefficients for individual basins and discussed some factors which contributed toward change. It was concluded that the drainage system in the Lower Piave was impacted by land transformation brought about by industrialisation and modernisation of agriculture. In essence, the evolution of pumping capacity is a reflection of the two different agricultural eras which have characterised the 20th century.

The drainage system and infrastructure installed during reclamation not only reflected existing technology, but was designed to accommodate the agricultural systems of the era. Runoff coefficients for pumping capacity requirements were calculated on existing field (or landscape) structures, which would normally be imposed on newly reclaimed lands. From the evidence of topographic maps and agricultural statistics, it is known that pre-modern agricultural landscapes consisted of a combination of open fields, closed fields and piantata. While pumping capacity alterations were needed to correct initial miscalculations and other unforeseen factors, the plateaus in Figure 6.6 indicate a period of relative hydraulic stability between 1936 and 1956.

The capacity increases starting in the late 1950's can in large part be attributed to the modernisation of agriculture, which radically simplified landscape structure. Further change is foreseen through the increased installation of subterranean drainage. Ironically, while subterranean drainage has negative impacts on surface water hydrology, it has a positive role in sustainable agricultural systems (Carrer 1993; Bustaffa & Soldati 1995). In summary, the relatively rapid transformation of the agricultural economy to a modern form played a large role in disrupting the earlier level of hydraulic stability, and necessitated further improvements to infrastructure.

From both a highly governed landscape and "health" perspective, land drainage and the historical developments just summarised are very significant. From a highly governed landscape perspective, drainage is the most important aspect of governance. Whatever the wisdom of developing in a flood prone area, administrative bodies must now seek to maintain reclaimed lands to protect human and economic interests. While periodic system maintenance and upgrading would seem to be a normal and inevitable part of land governance in reclaimed areas, the situation has been exacerbated by human actions in more recent times. This development, however, is not without its costs.

Economically, reclamation is an expensive proposition both in terms of initial reclamation costs and what has been spent to upgrade pumping capacity as a result of modern era landscape alterations[23]. Moreover, humans must now pay additional costs for proposed improvements to infrastructure based on the 1991 plan for improvement. On the whole, however, costs associated

[23]It was estimated that up to 1974, the total costs of reclamation and subsequent upgrades equalled 1.15 million lira per hectare (or $1035 1974 dollars based on current exchange rates), of which 33 percent was paid by the landowner (Fassetta 1977).

with changes in agriculture and increased urbanisation are difficult to estimate because there is no accounting for these indirect effects.

For example, the 1991 *Piano Generale di Bonifica* estimated a cost of 17.5 billion lira to retrofit and increase the capacity of 9 pumping stations found in the Lower Piave area. This translates to a cost of about 15.75 million Canadian dollars[24]. Exact cost breakdowns are not provided in terms of the proportion of this amount specifically devoted to pumping capacity upgrades. All that can be concluded is that a significant portion is directed toward increasing pumping capacity. Furthermore, this expenditure is not only a result of natural factors (e.g. sea level rise[25], subsidence), but also because of increased urbanisation and subterranean drainage.

Therefore from an overall economic standpoint, reclaimed areas require constant economic subsidy for their maintenance. In addition to government reclamation subsidies, individual landowners are also taxed to pay for improvements in reclaimed areas. This includes urban dwellers that are taxed because they are judged to benefit from hydraulic improvements. From a strict **economic sustainability** perspective, the system is economically viable only if the benefits of agricultural development surpass the economic costs of reclamation and continued governance. Unfortunately, there are no clear answers to this given the lack of empirical study as to costs and benefits. The overall benefits of agriculture may also be overstated given the substantial price supports[26] and surpluses inherent in European Agriculture. In light of unanswered economic sustainability questions and the need to continually govern this territory,

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[24]Assuming current exchange rates of $0.9 = 1000 lira.

[25]A sea level rise of about 48cm due to global warming is projected for the entire northeastern Italian coastal zone by the year 2100. Sea level rise will also be compounded by the natural rate of subsidence occurring in the region. This has been estimated at 0.3 to 0.4 mm per year (Bondesan *et al.* 1995).

[26]For example, at the time of the reform of the CAP in 1992-3, the "production aid" (or subsidy) to farmers for growing cereal crops (including wheat and corn) amounted to around 290,000 lira per hectare (or around 261 dollars at current exchange rates) (Commission of the European Communities 1993). Given these subsidies, reclamation and subterranean drainage costs can be recouped relatively quickly.

humans should strive to maintain stable water flows and drainage levels to at least reduce the economic and social costs of inhabiting a low lying area.

From a "health" perspective, the need to upgrade pumping capacity in the modern era because of landscape changes underscores the ecological significance of pre-modern landscape structures. In this regard, earlier landscape structures played an important role in controlling water flow and drainage. Elimination or alteration of these structures disrupted the measure of hydraulic stability, or **balance** that had been achieved after initial pumping capacity errors had been corrected. This disruption also included some undetermined economic costs. Therefore from a governance point of view, the maintenance of stable surface water flows is an important component of the "health" of highly governed landscapes. This fact has important implications for the interpretation of the biophysical landscape health concept and the management/governance of these landscapes.

6.4 WATER QUALITY

Water quality represents another critical landscape component of interest in the Lower Piave. Water quality is an important issue in any landscape ecological study because not only is it the most vital of resources, but is also closely tied to anthropogenic factors such as population and land use. The state of physical and chemical water quality parameters is also an important indicator of distress levels in aquatic ecosystems. As was discussed in Chapter 2, the level of system distress is an important indicator of system health. By extension, the quality of water flowing through watercourses and aquatic ecosystems can provide indications as to the "health" of landscapes.

Water quality and distress levels in aquatic ecosystems are an especially critical concern in the Northern Italian Plain as a variety of factors have combined to place severe stress on the once abundant and high quality water resources of the region. Chief among these is the post - W.W.II economic transformation which has brought widespread industrialisation to northern Italy and modernisation of agriculture; both with their attendant environmental externalities. To these factors must be added increased population and urbanisation occurring over the last half-century.

The net result of all these changes has been a marked deterioration in both the quantity and quality of this most precious resource over the last half-century. Most rivers in the region become polluted to varying degrees once they make their way down from Alpine and Apennine areas into the Northern Italian Plain. Subterranean aquifers are also endangered by heavy use of agricultural chemicals and land disposal of liquid animal wastes generated by industrial livestock operations. The quantity of both surface and ground water has also diminished given heavy demands from agricultural, industrial and domestic uses.

As with the rest of the Northern Italian Plain, the Lower Piave is facing significant surface and ground water quality problems as a direct result of the social and economic transformation of the last half century. By most accounts, water resources are in a deteriorated state and show little prospects of improvement (Zanetti 1990; Consorzio di Bonifica Basso Piave 1991; Carrer 1993; Regione del Veneto 1993; Turin *et al.* 1994). Pollution has been attributed to increased urbanisation, industrialisation and especially agricultural intensification. Dramatic increases in agricultural chemical inputs have been linked to toxic pollution and biological water quality problems in watercourses.

The following section examines existing historical trends related to surface and ground water quality, as well as possible connections between water quality distress and human activities. The main objective of this analysis is to assess the current status of Lower Piave water quality given empirical data is available for this period only. This analysis will provide important information as to human interactions with water resources.

1. Surface and Ground Water Quality in the Pre-Modern Era

Regarding past water quality conditions, the relatively recent occurrence of water monitoring makes it impossible to conduct an empirical comparison between conditions in the modern era and conditions during the subsistence agricultural era at the beginning of the century. However, examining circumstances can provide some indications as to past water quality. It is widely accepted that prior to widespread industrialisation and agricultural modernisation, the chronic water quality problems of today were largely absent. This is especially true in the case of toxicity and pollution loads related to industrial and agricultural runoff. Historical records indicate that up until 1914, water for domestic use by the comune of San Dona' di Piave was drawn directly from the Piave river (Fassetta 1977; Consorzio Aquedotto Basso Piave). At this time San Dona' was the only town in the area with an urban water infrastructure. Other area villages and farms relied on individual wells. Those without their own wells relied on the nearest available well. A frequent source of non-potable water was shallow wells commonly located in farm and village courtyards and drilled 5-8 metres into the nearest acquifer. In 1914, a more sophisticated water treatment system was devised and later constructed for San Dona', although water continued to be drawn directly from the Piave river.

Land reclamation and subsequent territorial colonisation increased the need/demand for water. This meant a more efficient and improved system of water provision and distribution was required. Under two national laws passed in the 1920's, including *the Bonifica Integrale Law* of 1928, the provision of potable water was mandated as a complementary aspect of land reclamation with the state government contributing no less than 75 percent of the costs. In 1933, a new law made water provision in reclaimed areas the full financial responsibility of the state government (Fassetta 1977).

The immediate result of these laws was increased drilling of wells into artesian acquifers to obtain water for public use in rural areas. In the lower Venetian Plain, these artesian aquifers are located at least 100 metres below surface level and are nourished by precipitation and surface water infiltrating the more permeable gravely soils of the upper Venetian Plain (see Figure 3.1) (Regione del Veneto 1988).

Given the hydrogeology of the Venetian Plain, ground water quality in the Lower Piave was good in the upper reaches, but tended to worsen towards the coastal zone. Towards San Dona`, artesian aquifers primarily fed by infiltration from Piave river waters provided a good quality source close to the surface. Further toward the coast, layers of decaying subterranean organic materials, built up over time in the marsh environment, and combined with the greater distances from aquifer recharge areas, produced poor quality ground water. This water was characterised by elevated temperature (18-20 degrees), yellowish colour, high methane and sulphur concentrations, and odours of hydrogen sulphate and iron. However, it was considered potable so long as bacterial pathogens were absent given it was the only source available for domestic use (Fassetta 1977).

Chronic ground water quality problems, decreasing flow of artesian aquifers, and the new problem of salt water penetration well upstream of the Piave river during high tide[27] provided the impetus for the search for higher quality water and a more efficient water distribution system. The result was the formation of the *Consorzio Acquedotto* in 1928. This saw the comuni and Consorzi between the Sile and Livenza rivers combine to establish a regional water authority. This authority sought to provide both urban and rural residents alike with a more coherent and reliable supply and distribution system of higher quality water. In 1935, six new wells and a reservoir were established in the vicinity of the comune of *Candelu`*. This commune is located in the *risorgive* belt (Map 6.2) (Fassetta 1977; Consorzio Acquedotto). The Consorzio Acquedotto was

[27]Presently, salt-water ions have been detected in the Piave river as far as Zenson di Piave, a community about 7 km north of San Dona` (Zaggia *et al.* 1996). Salt water concentrations have also been found to increase toward the mouth of the river (Zonta *et al.* 1996). The penetration of salt water up the Piave river has been largely attributed to hydroelectric dams in the Alps (first constructed in the1920's), which severely reduced the summertime flow of the Piave. This was compounded by heavy water withdrawals for irrigation with the intensification of agriculture in later years.

originally run by the individual *Consorzi di Bonifica* and the comune of San Dona`, but gradually evolved into the quasi-independent regional water authority of today. All communities in the Lower Piave were eventually connected to the water distribution network.

2. Present Water Quality Conditions

Today, the drinking water for all communities served by the Consorzio Acquedotto, and by extension the Lower Piave, is drawn from a series of wells located in the risorgive belt. The present state of ground water quality in the Lower Piave is not a concern. No monitoring is conducted as it has been dismissed long ago by the *Consorzio Acquedotto* as a viable resource for human consumption. However, while no empirical data is available, it is well known locally that ground water is severely degraded from agricultural and industrial pollution. The result is that unlike in the previous era, it is no longer even potable or fit for human consumption (Zanetti 1990).

Regarding surface water, the situation has changed considerably from the time in the early 1900's where water could be drawn from the Piave and used for domestic purposes with only bacteriological treatment, filtering and aeration (Consorzio Acquedotto). Two relevant analyses of surface water are provided for the Veneto Region (Regione del Veneto 1993; Turin *et al.* 1994). Both use different approaches and methodologies to rate the quality of surface waters in the region, including the principle watercourses in the Lower Piave. The former focuses on both biological integrity and human uses to derive water quality ratings, while the latter uses the application of an **Extended Biotic Index** (EBI) to assess water quality. These are both indices of ecological "distress" and were introduced in Chapter 2.

The Veneto Region provides the most comprehensive surface water quality picture through a program of monitoring of the Region's rivers undertaken in the 1980's (Regione del Veneto 1993). This includes the Brian canal system, which drains the territory between the Piave and Livenza. For the study, sampling was undertaken at a number of stations or sampling points over the period from 1985 to 1991. Monitoring was conducted for a total of 18 physical and chemical parameters. Water quality was then assessed and reported based on a rating system developed by ***IRSA-CNR***. The rating system emphasised the identification of distress and was reported in Table 2.2 in Chapter 2.

The results of this water quality monitoring and assessment program for sections of watercourses falling within the Lower Piave is presented in Table 6.12. The "global" category represents an overall quality assessment based on the seven most significant water quality parameters/indicators whose ratings are also illustrated in the table. These seven categories have been emphasised by the Veneto Region because they are deemed to be the best indicators of the biological integrity of water.

Table 6.12
***Regione del Veneto* Water Quality Ratings for 1985-1991 Period**

Parameter	Piave River	Livenza River	Brian-Bidoggia Canal
Global	1-2	1-2	1-2
Dissolved Oxygen	1	1	1-2
Biological Oxygen Demand	1	1	2
Chemical Oxygen Demand	1	1	2,3*
Ammonia (NH4)	2	2	2
Fecal Coliforms	2-3, 2**	2-3, 2***	2
Nitrates (NO3)	2-3	2-3, 3-4****	3
Phosphates (P)	2, 3+	3	2,4++

*Rating declines downstream from Sant'Anna di Boccafossa station.
**Rating improves downstream from Noventa di Piave station.
***Rating declines upstream from Torre di Mosto station.
****Rating declines upstream from Torre di Mosto station.
+Rating declines upstream from Noventa di Piave station.
++Rating declines downstream from Sant'Anna di Boccafossa station.

Source: Regione del Veneto 1993.

In relative terms, both the Piave and Livenza Rivers are regarded as some of the least polluted rivers in the Region. Their entire length has been rated as class 1-2, including the portions within the Lower Piave. However, in both cases there are problems regarding coliforms, nitrates and phosphates. In the Piave, bacterial pollution is particularly high in the tract between monitoring stations of Ponte di Piave and Noventa di Piave, as is the level of phosphates. It is notable that the dike containing the river begins at Ponte di Piave. The dike would prevent point sources of sewage from being discharged below this point. Thus it is likely that there are point discharges of untreated or inadequately treated sewage originating from the many urban nodes lining the floodplain above the dike. The nitrate problem likely derives from runoff in the rich agricultural region that surrounds the river in the upper plain.

For the Livenza, the situation regarding faecal coliforms and phosphates tends to improve downstream from the comune of *Torre di Mosto* and may be attributable to the fact that below this point there are fewer urban nodes to discharge sewage combined with greater water volume near the mouth. The poor situation with respect to nitrates is likely attributable to agricultural runoff in its upper reaches. Also, the Livenza's overall quality with respect to concentrations of **Cu, Cd** and **hydrocarbons** was found to lie somewhere between classes 2 and 3.

The *Bidoggia-Brian* canal/drainage system is fed by the *Monticano* torrent, originating in the mountains, and later by grid of canals in the Lower Piave. Globally, this system has been rated as class 1-2. Although this score indicates good quality, ratings are poor with respect to chemical oxygen demand, nitrates and phosphates. Conditions markedly deteriorate toward the *Revedoli* canal and mouth of the system. The intensity of agriculture in the lower reaches combined with the cumulative effects of runoff from the entire basin are likely contributing factors.

A slightly different picture of surface water quality is provided by Turin *et al.* (1994), who use the Extended Biotic Index (EBI) to assess water quality (see Table 2.1). Using this method and data collected between 1987 and 1992, the lower course of the Livenza river is rated as a **"lightly polluted"** environment (class II); the Lower Piave river is a **"polluted" environment"** (Class III); and the Bidoggia-Brian system is rated as a **"lightly polluted"** environment. Downstream from *Sant'Anna di Boccafossa*, the Brian canal becomes a **"polluted"** environment (Class III).

This evidence is reinforced by Loro *et al.* (1994) who include water quality evaluations using the same IBI in their assessment of fish populations in Treviso Province rivers. At monitoring points just before the Piave, Livenza, Bidoggia, and Grassaga[28] systems enter the Lower Piave, they are rated class II, class I, class II and class III respectively. As confirmed by Turin *et al.*'s values, both the Livenza and Bidoggia systems deteriorate downstream. This trend is expected as the quality of most Veneto region rivers tends to deteriorate as they flows from their source to the sea.

Upon review of the previous rating systems, some final conclusions have been drawn. In most cases, the **Livenza** river has been found to be a lightly polluted environment. The **Bidoggia-Brian** system ranges from lightly polluted to polluted, especially along its lower reaches. There is conflicting evidence regarding the **Piave** river which in some cases rates favourably. However, given the rating by Turin *et al.* (1994) (class III), problems related to coliforms, nitrates and phosphates, salt water infiltration and its turbid appearance up close, one concludes that it is a **stressed** river in terms of pollution.

When compared to the heavy pollution which exists in Po valley rivers, especially, these records indicate relatively low levels of aquatic ecosystem distress in the Lower Piave. However, many questions remain about local conditions (Zanetti 1990), and limitations inherent in these larger scale studies. Namely, while this information is useful in providing global ratings of water quality, it sheds no light on the condition of smaller canals and collector ditches in the Lower

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[28]The Bidoggia and Grassaga systems eventually combine within the Lower Piave to form the Brian Canal.

Piave. It also does not accurately depict localised pollution and point sources that are problematic with respect to bacterial pollution. And finally, monitoring is a relatively recent occurrence thus making it difficult to determine trends and account for fluctuations in water quality.

3. Water Quality Distress and Human Activities

Water quality distress conditions naturally arise out of the human activities in the Lower Piave. The main activities include **settlements, industry** and **agriculture,** which is by far the most dominant. However, there is considerable industrial activity dispersed throughout the area which is cause for environmental concern. Moreover, while the area is generally lightly populated, there are many urban nodes and ribbon development along major roads which discharge waste waters into drainage canals.

Industrial activities in the Lower Piave follow the typical Veneto model of light industry and laboratories located not only in larger settlements, but dispersed throughout the countryside. As a consequence of this form of organisation, it is difficult to monitor toxic wastewater discharges. There is also the potential for large amounts of untreated wastewater to be discharged into canals and watercourses outside the range of sewage treatment plants. Although empirical evidence is lacking, it is widely believed that "illegal" industrial discharges have contaminated some groundwater aquifers, poisoned ditches to the extent they constitute a hazard to human health, and have contributed toward the overall deterioration of surface water (Zanetti 1990).

Another problem is the illegal disposal of liquid wastes from industrial livestock operations. While there are environmental guidelines as to the amount of liquid animal wastes which can be spread on a given area of farmland, discharges above accepted limits are difficult to monitor. They are widely believed to contribute toward the pollution of surface and ground water (Zanetti 1990; Consorzio di Bonifica Basso Piave 1991). With both industrial and livestock operations, the monitoring of discharges is extremely difficult because discharges are irregular and difficult to trace to particular sources.

Urbanisation and ribbon development along roadways over this century has also made its contribution to water quality distress. One significant problem identified earlier was bacterial pollution. The availability of only limited macro-level data makes it difficult to get a proper handle on what is an extremely localised problem. The Consorzio di Bonifica Basso Piave (1991) identifies bacterial pollution as a chronic and worsening problem in watercourses receiving discharges from urban nodes and the tourist developments along the coast. This problem is compounded during summer as recreational use along the coast increases sewage discharges. In summer, these discharges are less easily diluted as water flows and velocities decrease as a result of reduced precipitation. Furthermore, of all the urban nodes in the Lower Piave, only the main centre of San Dona` di Piave has full primary and secondary chemical sewage treatment. Most other nodes have only partial secondary treatment or "simplified oxidation" compared to "full oxidation".

Urban areas also discharge heavy nutrient loads into area watercourses which pose eutrophication problems. As part of an overall study on water quality related to urban and agricultural-based discharges/runoff, the *Consorzio di Bonifica Basso Piave* (1995) examined nutrient levels in two canals during the 1989-1993 period. One canal receives wastewater discharges/runoff from the comune of San Dona, while the other from a large part of the comune of Ceggia. Table 6.13 lists nutrient loads in these canals, which can be compared with relevant water quality standards in Table 6.14. It should be noted that discharges/runoff from San Dona` were treated while those of Ceggia were untreated.

When assessing urban-based discharges, two different standards can be used as illustrated in Table 6.14. The Consorzio uses thresholds based on the benchmark *Merli* Law of 1976. This Law's objective was the integration and modification of existing patchwork legislation, and the

Table 6.13
Nutrient Levels in Urban Runoff/Discharges (mg/l)

Year		San Dona`		Ceggia	
		N*	P	N	P
1989-1990	Aver. conc. (all samples)	**19.7**	**1.00**		
	Maximum conc.**	72.8	2.02		
1990-1991	Aver. conc. (all samples)	**11.20**	**1.67**		
	Maximum conc.	30.50	3.37		
1991-1992	Aver. conc. (all samples)	**12.56**	**2.63**	**5.04**	**0.53**
	Maximum conc.	20.30	23.25	9.80	0.84
1992-1993	Aver. conc. (all samples)	**21.21**	**1.13**	**11.84**	**0.74**
	Maximum conc.	50.4	2.50	18.20	1.45
Average Values	Aver. conc. (all samples)	**11.2**	**1.0**	**5.06**	**0.53**
	Maximum conc.	21.33	2.63	11.84	0.74

*represents total nitrogen content including nitrates

**Average concentrations will fluctuate according to yearly precipitation and maximum concentrations arise from specific precipitation events of large magnitude.

Source: Consorzio di Bonfica Basso Piave 1995.

Table 6.14
Acceptable Nutrient Concentration Limits

Acceptable Concentration Limits:	N	P
Consorzio di Bonifica Basso Piave (1995) - *based on Merli Law n.319/1976.*	30 mg/l: urban discharges 20 mg/l: non-urban waterways	15-20 mg/l: Urban discharges 10 mg/l: non-urban waterways
Regione Del Veneto (1993) - *based on EU Directive n.440/75.*	5.6-11.3 mg/l - potability**	0.1 - 0.2 mg/l: potability 0.2 - 0.4 mg/l: aquatic life

**There are actually three subclasses of standard related to potability; with these values representing the best and worst regarding the acceptable range.

Sources: Regione Del Veneto 1993; Consorzio di Bonfica Basso Piave 1995.

implementation of new regulations regarding wastewater discharges to combat widespread water pollution. The law formulated general criteria for utilisation, distribution, monitoring and treatment of water in order to help develop a plan for the rehabilitation of water resources across the country. Included was the establishment of acceptable water quality limits or standards. Overall however, the Law has proven inadequate in protecting water quality and aquatic environments given the lack of implementation and enforcement, as well as the failure to take into account the effects of discharges in relation to the capacity of water courses to absorb discharges (Castaman 1995).

According to *Merli* law standards, average concentrations of **N** and **P** in wastewaters (Table 6.13) fall well within acceptable limits for the entire monitoring period. At worst, they only reach the boundary of unacceptable limits as in the case of **N** during two monitoring years at San Dona` station. If the more rigorous standards of the European Community are applied, however, the average value of N over the five year period is at the threshold of unacceptable limits and in three years exceeds the threshold at San Dona` di Piave station. Thresholds of **P** are greatly exceeded for both potability and aquatic life. Average values for **N** and **P** are considerably lower at the Ceggia station, but the thresholds of **P** are still exceeded. This has been attributed to the higher flow of the discharge canal, which is augmented by groundwater originating from the almost adjacent Piavon Canal (Map 6.3).

Based on EU directives, we would conclude that nutrient levels in wastewater discharges are at or above the threshold of acceptable distress limits, and would likely contribute toward eutrophication and diminished water quality problems in areas downstream from urban discharge sources. There are unanswered questions, however, as to the huge differences with respect to thresholds of acceptable **P** limits, and why the Consorzio Basso Piave uses the lower standards to assess nutrient loads. By using lower standards, the Consorzio concludes that nutrient loads related to urban discharges fall within accepted limits.

The Consorzio also concludes that nitrogen discharges per hectare of urban land are about 5 times greater than those from agricultural land; while phosphorous discharges per hectare of urban land range from 30 to 40 times greater than those per hectare of agricultural land. Based on these figures, total nitrogen discharge from the 7400 hectares of land designated as urban use within the entire Consorzio Basso Piave[29] is theoretically almost equivalent to the discharge from 37,000 hectares of agricultural land (Consorzio di Bonifica Basso Piave 1995). As there are 42,000 hectares of land classified as under cultivation[30] within the entire Consorzio Basso Piave, urban-based nitrogen discharges are almost equivalent to those from agricultural lands (or 88 percent of agricultural discharges). With phosphorous, discharges from the same urban area are theoretically equivalent to at least 220,000 hectares of agricultural land, or 529 percent of existing cultivated land. While extrapolations, these figures nonetheless indicate the proportional contribution of urban and agricultural areas to overall nutrient discharges.

Concerning the dominant activity of agriculture, it is expected that the high input agriculture practised in the region contributes substantially toward deterioration of surface and groundwater quality. As part of the previously cited study, the Consorzio Basso Piave examined nutrient and agricultural chemical discharges/runoff from three agricultural basins within the Lower Piave. A summary of key findings is provided by Tables 6.15 and 6.16 on the next page.

Using thresholds set by the *Merli* Law (Table 6.14), the Consorzio concludes that nutrient levels in collector waterways fall well within acceptable limits on average. The few times that concentrations exceed limits occur during events of heavy rain. The Consorzio also asserts that this evidence contradicts the widespread belief that intensive agriculture as practised in the region is responsible for excessive nutrient loads in watercourses. The Consorzio does, however, raise concern over the large percentage of N and K inputs lost to runoff, and recommends that they be

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[29]The entire Consorzio Basso Piave as illustrated in Map 3.2.

[30]Or "*superficie agricoltura utilizzabile*" (Consorzio di Bonifica Basso Piave 1991).

Table 6.15
Nutrient Levels in Agricultural Basin Runoff (mg/l)

Year		*Tre Cai* Basin (752 ha*, silty soils)		*Berengan* Basin (57 ha, sandy silt soils)		*Fossa`* Basin (316 ha, clay soils)	
		N**	P	N	P	N	P
1988-89	Aver. conc.	**2.59**	**0.05**	5.73	**0.025**	**8.38**	**0.067**
	Max. conc.	6.80	0.255	12.94	0.365	21.16	0.119
1989-90	Aver. conc.	**10.53**	**0.104**	**6.66**	**0.174**	**10.50**	**0.118**
	Max. conc.	27.2	0.18	16.50	0.4	30.80	0.230
1990-91	Aver. conc.	**8.49**	**0.104**	**6.86**	**0.137**	**8.76**	**0.129**
	Max. conc.	33.5	0.180	14.65	0.287	15.8	0.213
1991-92	Aver. conc.	**9.15**	**0.058**	**13.2**	**0.018**	**5.15**	**0.102**
	Max. conc.	13.6	0.120	17.7	0.166	10.48	0.135
1992-93	Aver. conc.	**5.22**	**0.045**	**5.13**	**0.197**	**3.17**	**0.078**
	Max. conc.	9.36	0.092	6.83	0.250	8.97	0.141
Aver. Val. 1988-93	Aver. conc.	**7.82**	**0.074**	**7.97**	**0.117**	**7.61**	**0.10**

*Total area of basin.
**Represents total nitrogen content including nitrates.
**Average concentrations will fluctuate according to yearly precipitation and maximum concentrations arise from specific precipitation events of large magnitude.

Source: Consorzio di Bonfica Basso Piave 1995.

Table 6.16
Average Total Nutrient and Chemical Runoff/Losses: 1988-93

		Tre Cai Basin		*Berengan* Basin		*Fossa`* Basin	
		kg/ha	% loss	kg/ha	% loss	kg/ha	% loss
N:	Inputs	153		97		135	
	Losses	19.5	12.7%	20.4	21%	27.5	20.4%
P:	Inputs	59		40		49	
	Losses	0.184	0.3%	0.3	0.75%	0.39	0.8%
*Fito-Farmaci:**	Inputs**	1.24		1.18		0.94	
	Losses**	.0024	0.19%	.0008	0.68%	0.017	1.8%

*Or agro-chemicals including pesticides, herbicides and fungicides. Represents total inputs of all chemicals.
**For corn and soybeans only.

Source: Consorzio di Bonfica Basso Piave 1995.

reduced using suitable agronomic techniques. If we were to extrapolate the average yearly loss of N in individual basins to the entire Consorzio Basso Piave (useable cultivation area of 42,000 ha), total yearly losses of N would range from 819, 856.8, and 1155 tonnes respectively, depending on soil conditions.

A different picture of discharges is provided by a comparison with standards set by European Community directives. Regarding N, concentrations tend to fall toward the lower end of acceptable limits for potability (11.3 mg/l), while average concentrations of **P** are just about at the level of acceptable limits (.1-.2 mg/l). This would indicate that levels of these critical nutrients are almost at their maximum threshold of acceptability.

In conclusion, existing empirical data allows us to draw only a few firm conclusions with respect to human activities and distress levels in Lower Piave water quality. The evidence from the Consorzio's analysis suggests, based strictly on discharges per land unit, that urban discharges contribute greater nutrient loads than agriculture. Nonetheless, agriculture is still responsible for large discharges of nutrients, which undoubtedly play an undertermined role in eutrophication and vegetation growth in waterways.

As for the entire issue of nutrient discharges, many unanswered questions remain. For example, what are actual total nutrient loads originating from both agricultural and urban sources? What is the cumulative effect of existing nutrient discharges on the smaller waterways and drainage canals that so far have not been monitored for water quality? Do even moderate discharges stimulate excessive growth of aquatic vegetation, which is undesirable as it clogs canals and reduces water flow. What is the extent of the liquid animal waste problem and its contribution to total nutrient concentrations and water pollution?

And finally, questions remain as to toxic loadings from agricultural chemicals. Table 6.16 indicates the total amount of agricultural chemicals lost vis-a-vis inputs. The Consorzio does not list concentrations of these chemicals in drainage water, but claims that they fall well within limits set by the *Merli* Law. However, are these limits stringent enough, and what are the effects of even these small quantities on local ecotopes? What happens to agricultural chemicals applied since the data indicate large quantities are not lost to runoff? Do they persist in soils for long periods of time and do they eventually leach into groundwater?

Overall, it is clear that there is insufficient data to draw many firm conclusions regarding the long term and cumulative effects of human activities on water quality and aquatic ecosystems. More comprehensive monitoring of watercourses and aquatic ecosystems is required to more firmly determine levels of aquatic distress and its causes. So are strategies to assess the cumulative impacts of high chemical input agriculture on the water and ecology of the numerous ditches and canals draining the Lower Piave basin.

6.5 VEGETATION

1. Introduction

The final landscape element to be analysed in terms of change and current condition is vegetation. The landscape history in Chapter 3 discussed historical landscape changes with regards to vegetation and agriculture. Most significantly, the landscape history identified traditional cultivation systems and how they were rendered obsolete with the industrialisation of Italy and the subsequent modernisation of agriculture.

Maps 5.2 and 5.3 illustrate the transformation of landscapes where traditional cultivation systems and associated hedgerows and piantata were eliminated to accommodate the needs of the new agricultural economy. The maps, however, only illustrate landscape level trends, and do not provide any indication of qualitative or quantitative losses of vegetation when traditional cultivation systems were eliminated. Therefore, the purpose of this section is to:

1) Examine the structural changes of vegetation in greater detail to obtain a better idea of the quantitative and qualitative losses of vegetation when hedgerows and piantata were removed in the modern era, and;

2) To determine the significance of this loss in terms of the ecological functions provided by vegetation structures.

The analysis of vegetation concerns itself with temporal changes in hedgerow and piantata structures in the landscape. This is because traditionally, these structures can be considered as the "natural" vegetation in Venetian landscapes after the gradual elimination of most natural terrestrial areas. This is especially true in the Lower Piave, where the original marshes (and their characteristic vegetation) were eliminated through reclamation, and replaced with cultivated lands characterised by their own distinct vegetation structures and communities.

2. Methodology for Analysis of Vegetation Change

The methodology for the analysis of vegetation structural change consists of four steps (as first identified in Chapter 4), which are now described in greater detail. The four steps consist of:

1) Selection of two land cells within the Lower Piave area.
2) Identification and recording of vegetation corridors in each cell.
3) Graphical presentation and comparison of structural change between 1954 and 1983.
4) Interpretation of structural change in terms of vegetation composition.

1) Selection of two land cells within the Lower Piave area. Two cells within the Lower Piave area were selected in order to provide a reasonably representative sample of landscapes for analysis. The ***Grassaga*** area cell is an area of centuriation where traditional agricultural landscapes have been established for long periods of time. The area of this cell is 896 hectares. The ***Staffolo*** basin cell comprises a more newly reclaimed area located adjacent to the *Canal Brian*. The area of this cell is 310 ha.

2) Identification and recording of hedgerow corridors in each cell. Hedgerow corridors and other significant vertical vegetation structures (e.g. piantata, *arbusto* structures) were identified from the interpretation of both 1954 and 1983 series air photos available for the two areas. These two periods represent the pre-modern and modern eras. Hedgerows and other vegetation structures were recorded by tracing their corridors (or linear structure) onto overlays. These structures are entirely linear, as there are no wooded areas. The linear corridors were then digitised using MapInfo software.

The length of hedgerows and other vegetation elements are important indicators of vegetation structure - especially in governed and highly governed agricultural landscapes where hedgerows represent the dominant vegetation feature. Applications of this principle are found in Burel and Baudry (1990), Ihse (1995), and to a lesser extent, Medley *et al.* (1995). Burel and Baudry use length of hedgerows, their connectivity, and grain size (their density) as indicators of landscape change in Brittany France. Their analysis of hedgerows is based on 400 by 400 metre square grids (or cells). Ihse considers linear elements such as tree rows, along with field size, patches of semi-natural vegetation and point elements as ecological parameters to assess landscape changes in Sweden over the last 60 years. In Medley *et al.*, landscape structure, including hedgerow corridors, was one of the parameters used to examine temporal change in southwestern Ohio agricultural landscapes.

Hedgerow length and connectivity are significant from a landscape ecological perspective because hedgerows not only represent an important landscape vegetation component, but also serve as corridors for the migration and transfer of genes among species. The more connections there are, the more opportunity for interchange among species. Furthermore, intersections among hedgerows form mini-nodes of higher species diversity. This is likely derived from the microclimatic effects of intersections (Forman & Godron 1986). Thus vegetation structure plays an important role in maintaining biological diversity, which is normally identified as necessary condition of ecological integrity.

3) Presentation and comparison of structural change between 1954 and 1983.
From the digitised information, two sets of maps have been produced showing vegetation corridors in both 1954 and 1983 for both cells. The software also calculates the total length of linear vegetation features (per hectare) for each time period. The maps and linear measures illustrate, both visually and empirically, changes to vegetation structure occurring over the 30-year period of comparison.

4) Interpretation of structural changes in terms of vegetation composition. This step seeks to relate quantitative structural changes to qualitative changes in vegetation. In other words, what has been the effect of landscape transformation/simplification on vegetation composition? This is done by examining typical vegetation communities in traditional Venetian governed agricultural landscapes and comparing this to present vegetation and landscape conditions. An idea of the nature of vegetation that typically existed in Venetian agricultural landscapes is available through some existing vegetation studies/catalogues. Comparison of these catalogues with present conditions in the Lower Piave then provides some idea of what has been lost with the transformation of landscapes.

3. Analysis of Vegetation Change: *Grassaga* Area Cell

The first cell chosen for analysis is an area of centuriation, which is illustrated in Figure 3.3 and discussed in Chapter 3 during the discussion on Roman influences. This is considered to be representative of older, unreclaimed, agricultural landscapes in the Lower Piave. In the pre-modern era, agricultural landscapes were characterised by enclosed fields further subdivided by piantata. This landscape configuration is clearly indicated on the 1954 air photo shown on Figure 3.3. The different grey-toned rectangular areas represent individual fields. Given the time of year (April), and what is known about the practice of agriculture during the era, one would expect to see at ground level a mixture of bare plowed fields, fields in pasture, and fields sown in forage crops and winter wheat.

The thicker, darker lines separating the fields have been identified as significant linear vegetation corridors. The lack of vertical relief or height associated with these structures suggests that the grid is comprised of low-lying structures such as rows of *piantata*, *arbusti* (schrubs, bushes), or structures that are frequently coppiced. Sample structures of *arbusti* and coppice hedgerows typical of the Venetian Plain are illustrated in Figures 5.2[31], 6.7, 6.8, and 6.9.

Surprisingly, well-developed hedgerows with large mature trees, which are still common in much of the upper Venetian Plain, are not widespread in this cell. Denser hedgerows would normally consist of a three-tier structure of tall mature trees, *arbusti*, and herbaceous plants. A sample is illustrated in Figure 6.10. The piantata structure was dominated by hedge maple *(Acer campestre)*, white willow *(Salix alba)* and mulberry *(gelso)* trees holding up vines, and usually coppiced at 1.5 metre heights. Sometimes there were double rows; occupying a width of 4 to 5 metres (Sereni 1961; Tempesta 1989).

The existing grid of detectable vegetation[32] in both 1954 and 1983 is illustrated in Figure 6.11. The almost total disappearance of any kind of trees or bushes by 1983 is consistent with the landscape analysis of Chapter 5. The total length of hedgerows/piantata in 1954 equalled 62,960 metres, or 70.3 metres per ha, while in 1983 the length was reduced to only 2,926 metres or

[31] The predominantly black locust hedgerow in Figure 5.2 has grown to heights typical of mature trees. However, during the subsistence agricultural era, this would have been periodically cut for fuel or building materials.

[32]This is an important qualification given frequent cutting of hedges and trees in a piantata. Recently cut or coppiced vegetation can only be detected by photo tone if it represents a wide strip, rather than vertical height.

Figure 6.7
Example of Arbusto Hedgerow

Photo by: G. Mezzalira (Vianello & Vita 1994).

Figure 6.8
Example of Black Locust Coppice Hedgerow

Figure 6.9
Examples of Willow Coppice Hedgerows

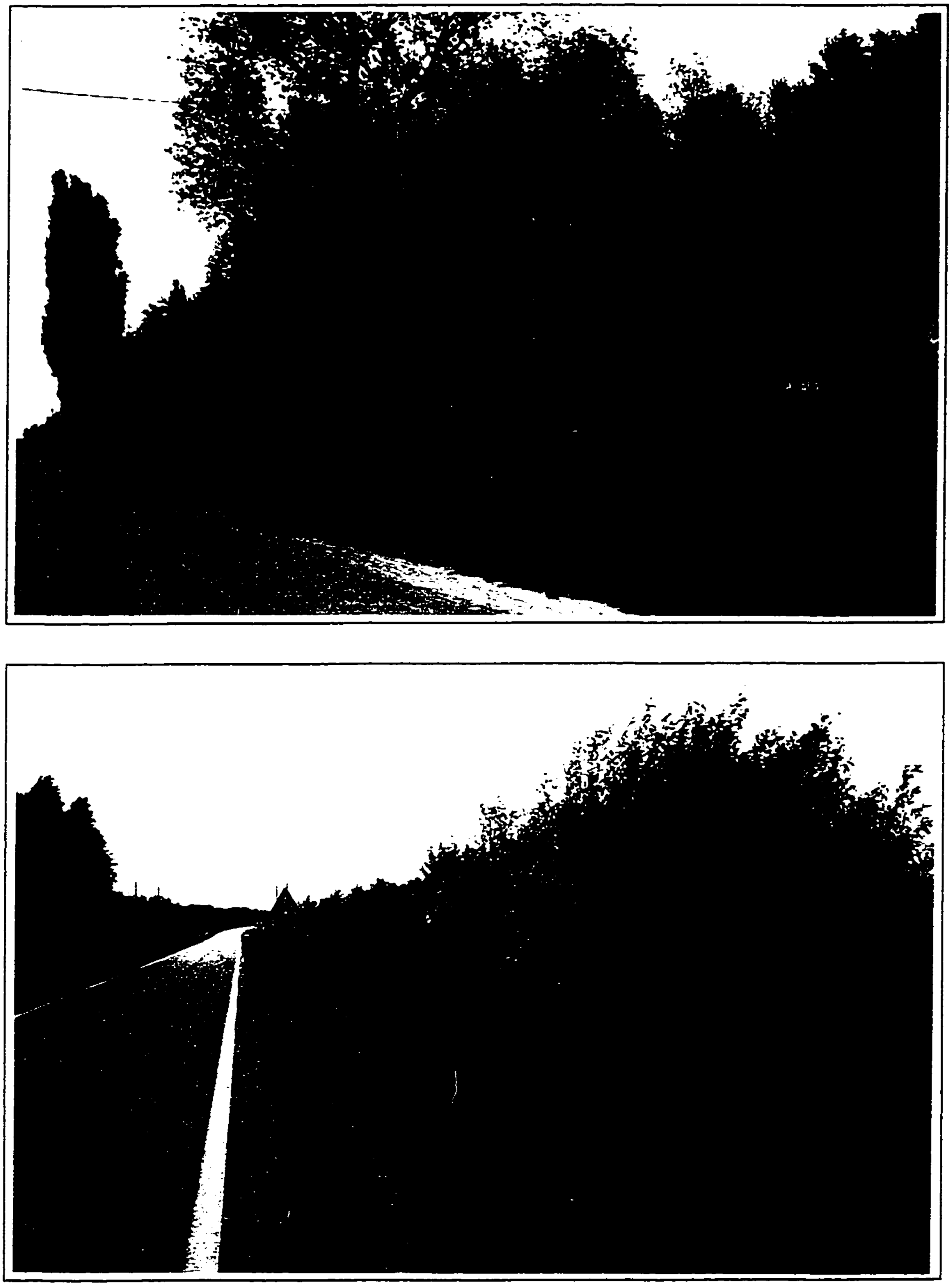


Figure 6.10
Examples of Three Tier Structure Hedgerows

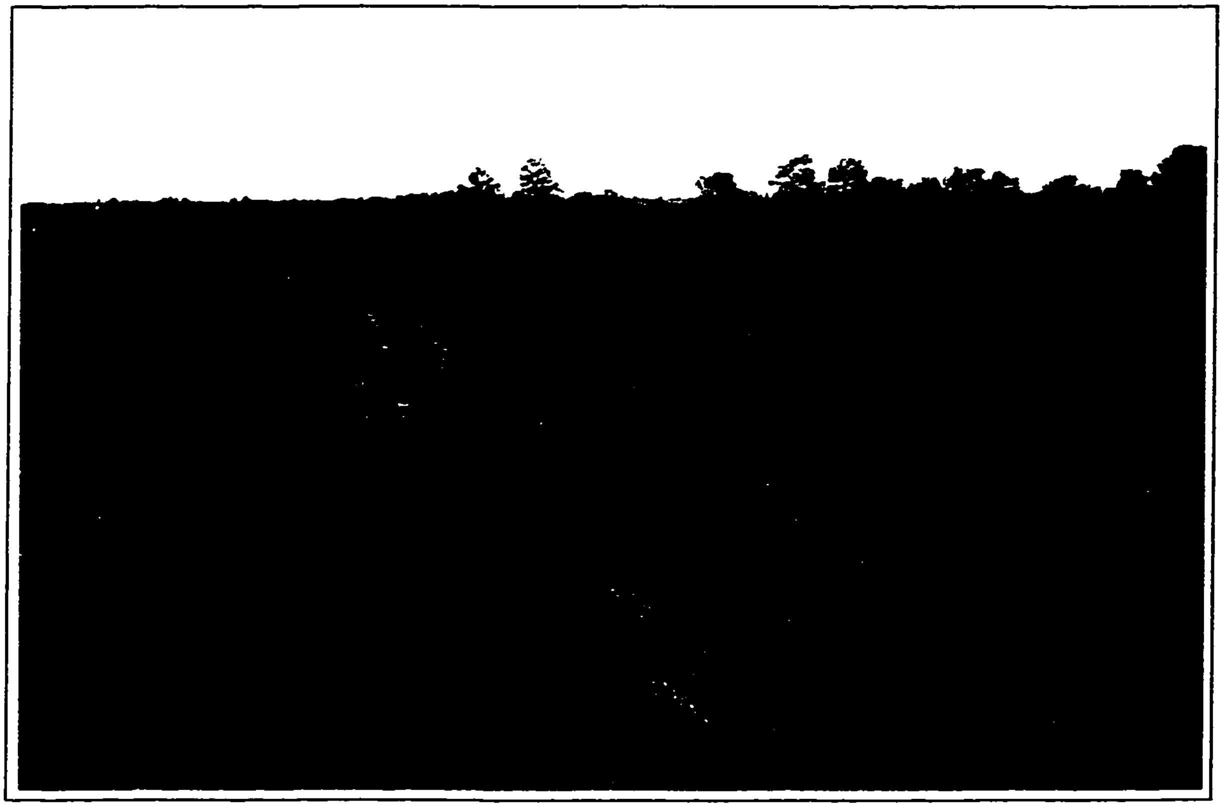
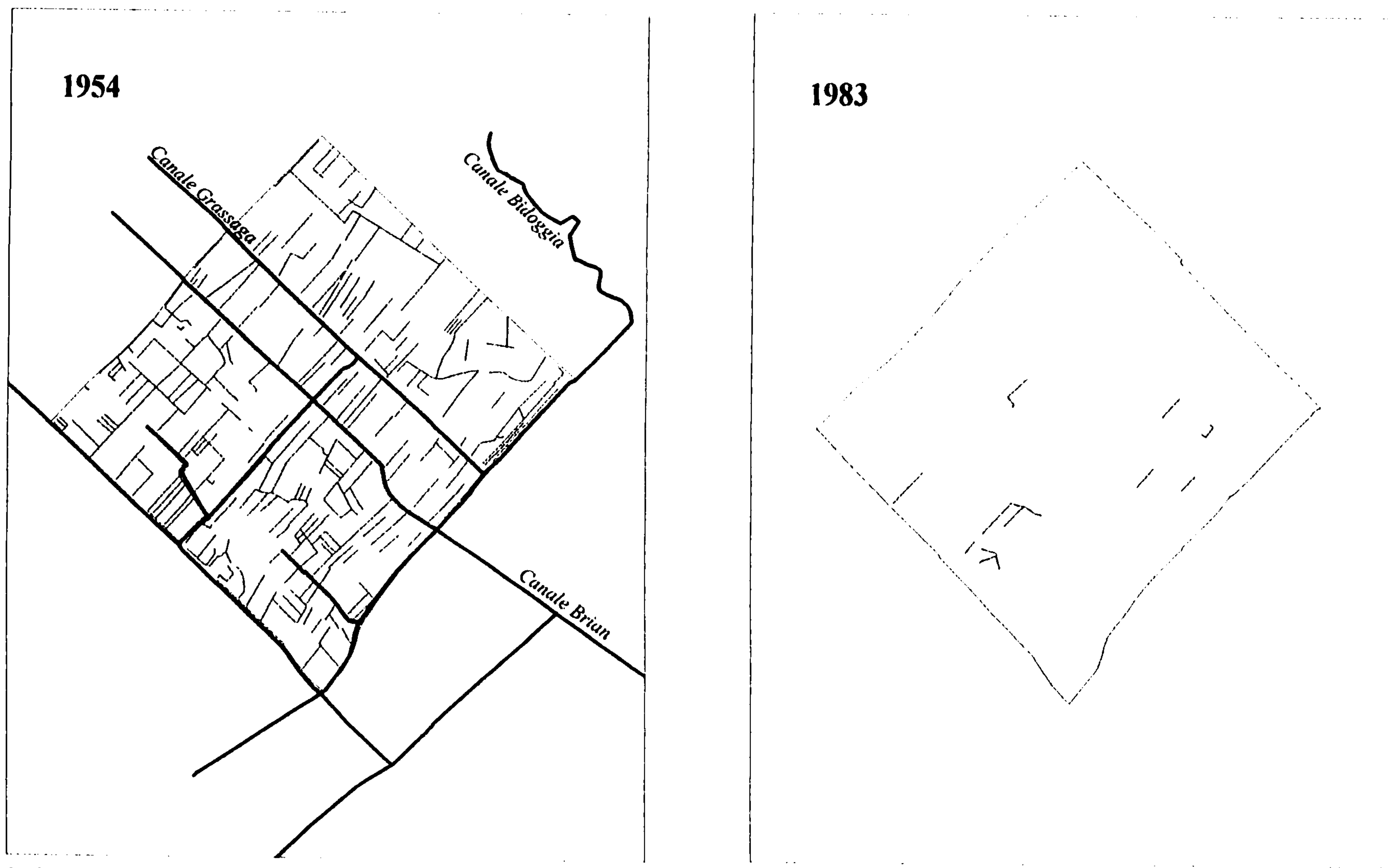


Figure 6.11: Grassaga Area Vegetation Networks - 1954 & 1983



Scale: 1 in = 1250 metres

Total Area = 896 hectares

3.3 m\ha.

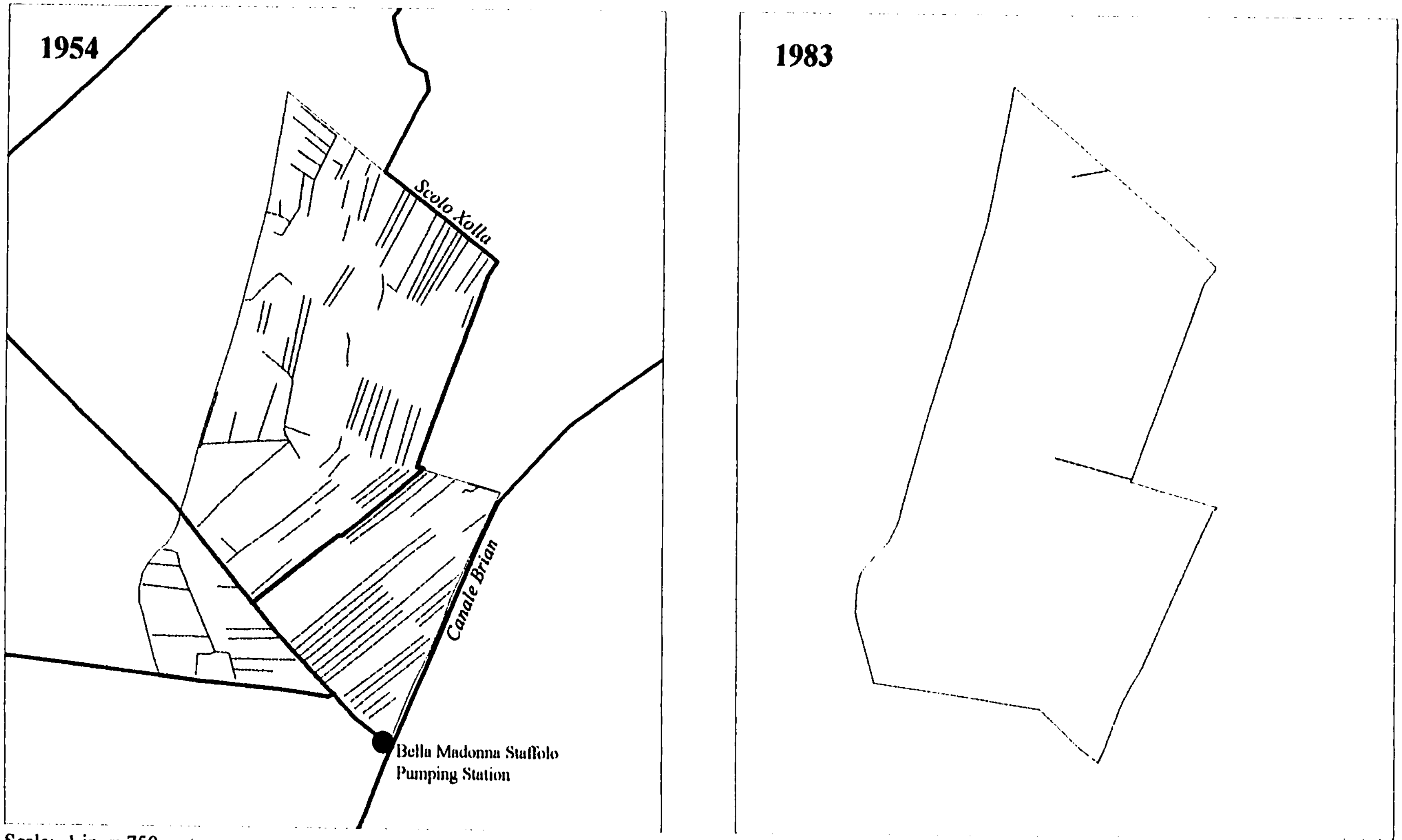
Structurally, a predominantly NE/SW linear pattern of vegetation corridors existed in 1954. Many larger hedgerows also ran perpendicular to this pattern to produce some degree of connectivity in the vegetation pattern. The pattern of fields and vegetation detected in the photo analysis is also oriented with the drainage system developed to drain this part of the Lower Piave area. Field ditches for the most part ran parallel to the slight contours of the land. The grid of field ditches is clearly evident in the cartographic image in Figure 3.3. These ditches then feed into other ditches or larger canals running perpendicular to the contours of the land.

4. Analysis of Vegetation Change: *Staffolo* Basin Cell

The second cell chosen for analysis is located in the *Bella Madonna-Staffolo* basin. This is roughly located on the northwest side of the Brian Canal between *Stretti* and *Torre di Mosto* (Map 6.3). It can also be identified by the location of the ***Staffolo*** pumping station on Map 3.2, which is situated on the bottom tip of the cell. Topographic maps show that this area was reclaimed around the turn of the century. Topographic maps of the 1960's indicate a landscape of piantata and closed fields. The air photo also shows a landscape structure of long and narrow fields divided by thin, well-defined strips of vegetation (identified by the darker tones on the air photo). The lack of vertical relief on these vegetation strips suggests that vegetation is likely comprised of low lying rows of piantata, *arbusti* or coppice woods.

The existing grid of vegetation in both 1954 and 1983 is illustrated in Figure 6.12. In 1954 there was a clear linear pattern to vegetation, which reflected *piantata* cultivation systems and the planting of low hedges or coppice woods between many of the fields. The virtual disappearance of all linear vegetation features by 1983 is again consistent with the findings from the previous cell. The total length of detectable vegetation corridors/structures in 1954 equalled 29,950 metres, or 97.5 m/ha. In 1983 the length was reduced to only 566 metres.

Figure 6.12: Staffolo Basin Vegetation Networks - 1954 & 1983



Scale: 1 in. = 750 metres

Total Area = 310 hectares

5. Interpretation of Vegetation Structural Change

The empirical comparison of the two years provides a measure of the linear vegetation corridors that were lost as a result of land transformation in these two selected areas. No quantitative studies are available, however, concerning the total amount of biomass and species lost for a larger area such as the entire Lower Piave. Furthermore, quantitative analyses of vegetation loss are naturally limited by inability to go back in time to verify what actually existed in terms of total vegetation composition.

Nonetheless, some idea of what was lost can be garnered through available literature and catalogues. This is based on the premise that vegetation structure and composition is similar throughout the Northeastern Italian plain. Zanetti (1988) identifies a total of 55 species of imported or native trees and *arbusto* species found throughout hedgerows of the Veneto. 50 of these are (or were) typical of the lower part of the Venetian Plain. Studies by Schirato (1991) and Targa (1990) provide two rare[33] (and revealing) breakdowns of existing hedgerow vegetation through their look at the relationships between agriculture, vegetation and macroinvertebrates/ pedofauna on two locations within the province of Treviso[34].

Schirato examines a centuriated area near Asolo, while Targa examines the location of a 12th century reclamation of a Benedictine estate in the upper Venetian Plain. Each author conducted an inventory of the species found in existing hedgerows. Typical species are shown on Table 6.17 on the next two pages. Six species of trees, fifteen and sixteen species respectively of shrubs *(arbusti)*, and twenty-nine species of herbaceous plants were identified. Many of the species and families are similar given the geographical proximity of the two locations. Typical tree species include hedge maple *(Acer campestre)*, black locust *(Robinia)*, sycamore *(Platanus)*, poplar *(Populus)*, willow *(Salix)*, elm *(Ulmus)* and oak *(Quercus)*. White willow (or *Salix alba*)

[33]A significant constraint to this analysis is that studies of this nature are rare and not well publicized.

[34]For location of the province of Treviso, see Map 3.1.

Table 6.17
Species Present in Hedgerows Tracts - Treviso Province

Schirato (1991):		Targa (1990):	
Family	Species	Family	Species
Arboreal Tier:			
Aceraceae	*Acer campestre L.*	*Aceraceae*	*Acer campestre L.*
	Acer obtusatem Waldst et Kit		
Leguminosae	*Robinia pseudoacacia L.*		
Platanaceae	*Platanus hybrida L.*	*Platanaceae*	*Platanus hybridus L.*
Salicaceae	*Populus nigra L.*	*Salicaceae*	*Populus alba L*
			Populus nigra L.
			Salix alba L.
			Salix purpurea L.
Ulmaceae	*Ulmus minor Miller*	*Ulmaceae*	*Ulmus glabra Miller*
			Ulmus minor Miller
		Betulaceae	*Alnus glutinosa L*
		Fagaceae	*Quercus robur L*
Arbustive Tier:			
Araliaceae	*Hedera helix L.*		
Canabaceae	*Humulus lupulus L.*	*Canabaceae*	*Humulus lupulus L.*
Caprifogliaceae	*Sambucus nigra L.*	*Caprifogliaceae*	*Lonicera caprifolium L.*
			Sambucus nigra L.
			Viburnum opulus L.
Celastraceae	*Euonymus europaeus L.*	*Celastraceae*	*Euonymus europaeus L*
Cornaceae	*Cornus sanguinea L.*		
Corylaceae	*Corylus avellana L.*	*Corylaceae*	*Corylus avellana L.*
Moraceae	*Morus nigra L.*		
Rhamnaceae	*Frangula alnus Miller*	*Rhamnaceae*	*Frangula alnus Miller*
			Rhamnus catharticus L.
Rosaceae	*Crataegus monogyna*	*Rosaceae*	*Crataegus monogyna*
	Prunus avium L.		*Prunus spinosa L.*
	Prunus cerasifera Ehrth.		*Rosa spp. L.*
	Prunus persica L.		*Rubus fruticosus L.*
	Prunus spinosa L.		
	Rubus idaeus L.		
Vitaceae	*Vitis vinifera L.*		
		Cynomoriaceae	*Cornus sanguinea L.*
		Ranuncolaceae	*Lonicera caprifolium L*
			Sambucus nigra L.
			Vibernium opulus L.
Principal Herbacious Plants:			
Aristolochiaceae	*Aristolochia clematitis L.*	*Anarylidaceae*	
Caryophyllaceae	*Silene vulgaris Moench*	*Caryophyllaceae*	
Chenopodiaceae	*Chenopodium album L.*		
Composite	*Achillea millefolium L.*	*Compositae*	
	Artemisia vulgaris L.		
	Aster novi belgii L.		
	Bellis perennis L.		
	Cirsium sp.		
	Taraxacum officinale Weber		

Cruciferae	*Capsella bursa-pastoris L.*	*Convulvolaceae*	
Euphorbiaceae	*Euphorbia cyparissias L.*	*Euphorbiaceae*	
Labiatae	*Ajuga reptans L.*		
	Lamium album L.		
	Salvia pratensis L.		
Leguminosae	*Trifolium repens L.*	*Leguminosae*	
	Trifolium pratense L.		
	Medicago sativa L.		
	Lotus corniculatus L.		
Liliaceae	*Colchicum autumnale L.*	*Liliaceae*	
Plantaginaceae	*Plantago lanceolata L.*	*Plantaginaceae*	
	Plantago maior L.		
Polygonaceae	*Rumex acetosa L.*	*Polygonaceae*	
	Remex obtusifolius L.		
Ranuncolaceae	*Ranunculus repens L.*	*Ranuncolaceae*	
	Thalictrum aquilegifolium L.		
Violaceae	*Viola arvensis Murr.*	*Umbrelliferae*	
Umbrelliferae	*Daucus carota L.*	*Violaceae*	
Urticaceae	*Parietaria officinalis*		
	Urtica dioica L.		
		Boraginaceae	
		Cyperaceae	
		Dipsaceae	
		Equisetaceae	
		Iridaceae	
		Labiateae	
		Nyctaginaceae	
		Oxalidaceae	
		Primulaceae	
		Rubiaceae	
		Valerianaceae	

Sources: Schirato 1991 and Targa 1990.

hedgerows (Figure 6.9) are (were) especially common in reclaimed areas. This species was frequently planted along ditches and watercourses because it is an easily propagating riparian species that thrives in moist soils. This fast grcwing tree also produces straight branches, which in the past served as building materials and fuel for cooking and heating (Zanetti 1988).

As for species distribution and frequency, Schirato (1991) provides a sample inventory of tree and shrub species over a one hundred-metre length of *arbusto* hedgerow. This is illustrated in Table 6.18 on the next page. While it is unwise to extrapolate too much from a single study, some aspects of this inventory are nonetheless worth noting. Eleven species of trees and shrubs were catalogued. In terms of density, *arbusto* species were spaced every 1.23 metres on average.

Frequent tree specimens included species such as hedge maple *(Acer campestre)* and black locust *(Robinia)*. Both of these are extremely common throughout the northeastern Italian plain. The majority of species are also less than five centimetres in diameter. This indicates frequent cutting or coppicing of tree species especially. This practice is still occurring today as wood fuel is still widely used as a supplementary heat source.

Table 6.18
Number of Species Present in 100 m of *Arbusto* Hedgerow

Species	Diameter of Trunk			
	<5 cm	5-10 cm	10-30 cm	Total
Populus nigra L.	0	0	3	3
Acer campestre	11	0	0	11
Robinia pseudoacacia L.	27	0	0	27
Prunus cerasifera Ehrh.	1	0	0	1
Prunus persica Stok.	1	0	0	1
Crataegus monogyna Jacq.	8	0	0	8
Euonymus eropeus L.	8	0	0	8
Sambucus nigra L.	3	1	0	4
Cornus sanguinea L	12	0	0	12
Frangula alnus Mill	4	0	0	4
Hedera helix	2	0	0	2
Total number of specimins	77	1	3	81
Number of species	10	1	1	11

Source: Schirato, 1991.

Cataloguing of species by Schirato also revealed how more developed hedgerows, with three tiers of vegetation, normally hold larger numbers of species and specimens. In this case, a one-hundred metre length of hedgerow holds seventeen species and one-hundred and twenty-four tree and arbusto specimens spaced an average of eighty centimetres apart. Forty-one specimens were black locust trees. An even more complex three-tier hedgerow structure lining both sides of a drainage ditch produced nineteen species and one hundred and eighty-nine tree and *arbusto* specimens.

6. Significance of Vegetation Loss

In addition to the obvious loss of vegetation specimens and biomass, a number of other consequences arose from the elimination of hedgerows and piantata from agricultural landscapes. These consequences relate to the productive and ecological functions provided by hedgerows and other vegetation structures. In Chapter 3, the productive functions of hedgerows and piantata in a subsistence agricultural system were outlined. In addition to these material and resource functions, hedgerows also serve(d) a variety of beneficial ecological functions. While the loss of productive functions is less relevant given the disappearance of subsistence agriculture, the loss of ecological functions is still significant from a landscape health point of view.

This section deduces the significance of vegetation loss through examination of the normal ecological functions provided by hedgerow vegetation. Ecological functions provided by hedgerows are well documented by studies found in the literature. **By knowing these relationships, one can accurately deduce the probable ecological consequences of vegetation loss without having to undertake direct cause-effect empirical studies.** In Chapter 7, this information assists with the definition of key landscape linkages and the interpretation of landscape health.

Habitat Function and Reservoir of Biological Diversity

There is ample evidence to conclude that hedgerows play an important role in the maintenance of biological diversity (species composition and abundance) in agricultural landscapes where the original forest ecosystem has been eliminated. In the first place, hedgerows themselves constitute complex vegetation communities consisting of significant numbers of floral species (Zanetti 1988; Mezzalira 1990; Urbinati 1994; Vianello & Vita 1994). The vegetation catalogues in the previous section demonstrated this.

Hedgerows also serve as important habitat for fauna, thus affecting the diversity and populations of animal, insect and macroinvertebrate species. Table 6.19 provides an inventory of some of the common animal and insect species found in the hedgerows of traditional northeastern Veneto agricultural landscapes. Included are four species of molluscs, fifty-one species of insects, eight species of amphibians, six species of reptiles, forty-one species of birds and nine species of mammals. Hence, the removal of hedgerows would eliminate faunal habitat with a corresponding loss of faunal diversity.

Table 6.19
Faunal Diversity of Northeastern Veneto Hedgerows

Category of Fauna	Genus - Species	
Molluscs	*Helix aspersa*	
	HelixpPomatia	
	Cepaea nemoralis	
	Cyclostoma sp	
Insects	*Agrion puella*	*Staphylinus olens*
	Aeschna cyanea	*Silpha atrata*
	Tettigonia viridissima	*Luciola italica*
	Gryllotalpa gryllotalpa	*Cantharis rustica*
	Forficula auricularia	*Lytta vesicatoria*
	Carpocoris pudicus	*Coccinella septem-punctata*
	Lyriser plebejus	*Thea vigintiduo-punctata*
	Palomena viridissima	*Melolontha melolontha*
	Cercopsis sanguinolenta	*Phillopertha horticola*
	Macrosilphum rosae	*Cetonia aurata*
	Panorpa communis	*Curculio necum*
	Chrysopa perla	*Culex pipiens*
	Melanthia procellata	*Asilus sp.*
	Herse convolvuli	*Syrphus pyrastri*
	Acherontia atropos	*Volucella pellucens*
	Saturnia pyri	*Lucilia sericata*
	Eudia pavonia	*Arge rosae*
	Aporia crataegi	*Ophion luteus*
	Gonepteryx rhamni	*Apanteles glomeratus*
	Vanessa cardui	*Macrocentrus abdominalis*
	Inachys io	*Rhodites rosae*
	Vanessa atalanta	*Lasius niger*
	Parage megaera	*Vespa crabro*
	Carabus coriaceus	*Sceliphron spirifex*
	Carabus violaceus	*Xilocopa violacea*
		Apis mellifica

Amphibians	*Triturus vulgaris* *Salamandra salamandra* *Pelobates fuscus* *Bufo viridis* *Bufo bufo* *Rana latastei* *Rana dalmatina* *Hyla arborea*
Reptiles	*Anguis fragilis* *Podarcis muralis* *Lacerrta viridis* *Coluber viridiflavus* *Coronella austriaca* *Natrix natrix*
Birds	*Accipiter nisus* *Phasianus colchicus* *Scolopax rusticola* *Columba palumbus* *Streptopelia turtur* *Cuculus canorus* *Athene noctua* *Asio otus* *Jynx torquilla* *Hirundo rustica* *Lanius collurio* *Oriolus oriolus* *Sturnus vulgaris* *Pica pica* *Troglodytes troglodytes* *Cettia cetti* *Hippolais polyglotta* *Sylvia borin* *Slyvia atricapilla* *Sylvia communis* *Phylloscopus sibilatrix* *Phylloscopus trochilus* *Regulus regulus* *Erithacus rubecula* *Luscinia megarhynchos* *Turdus merula* *Turdus iliacus* *Turdus philomelos* *Turdus pilaris* *Parus coeruleus* *Parus major* *Aegithalos caudatus* *Passer domesticus* *Passer montanus* *Fringilla coelebs* *Pyrrhula pyrrhula* *Coccothraustes coccothraustes* *Carduelis chloris* *Carduelis carduelis* *Emberiza calandra* *Emberiza cia*
Mammals	*Erinaceus europaeus* *Dorex araneus* *Crocidura suaveolens* *Muscardinus avellanarius* *Apodemus sylvaticus* *Martes foina* *Mustela nivalis* *Mustela putorius* *Meles meles*

Source: Zanetti, 1988.

Furthermore, the removal of hedgerow vegetation also has implications for overall biological diversity in agricultural landscapes. It has been demonstrated that northeastern Italian agricultural landscapes characterised by polycultures and smaller fields separated by hedgerows have a higher macrofauna[35] species diversity than landscapes of extensive open fields and monocultures (Nazzi *et al.* 1988; Targa 1990; Schirato 1991; Paoletti 1993b; Paoletti 1995; Paoletti & Bressan 1996). From this evidence, it can be concluded that the widespread elimination of hedgerows in the Lower Piave has not only eliminated habitat and species from the area, but also significantly reduced overall biological diversity. In fact, the condition usually referred to as a "green desert" easily applies to the Lower Piave. Intensive agriculture produces lush vegetation in the summer but has resulted in an overall impoverishment of biological diversity compared to traditional Venetian landscapes.

Erosion Control Function

The existence of hedgerows along ditches and watercourses provides important erosion protection for their banks and reduces the rate at which canals fill up with sediment (Zanetti 1988; Mezzalira 1990). Severe slope and bank erosion problems are clearly evident throughout the Venetian plain where ditches and canals are devoid of vegetation. The filling up of watercourses and loss of trapezoidal shape is a significant concern for the *Consorzi di Bonifica* in light of problems mentioned in section 6.3. As stated in Chapter 5, ditches always required regular maintenance that was once accomplished by human labour, but is now mechanised. Within farm fields, the installation of subterranean drainage is to a large degree seen as a remedy to costs of regular ditch maintenance (Consorzio di Bonifica Basso Piave 1991). This solution, however, is itself costly as Section 6.3 demonstrated how subterranean drainage also negatively affects peak water flows and surface water drainage.

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[35]Such as earthworms, ants, woodlice, millipedes, centipedes, spiders, beetles, etc.

Water Quality Control

Hedgerows also provide an important water quality control function. From an overall landscape ecological perspective, hedgerows are deemed to have a beneficial effect on water quality because they inhibit the runoff of soil and nutrients from fields (Forman & Godron 1986). From a Veneto regional perspective, vegetation along ditches and watercourses provides identifiable benefits to water quality. Arboreal species along ditches absorb nutrients (phosphates, nitrates) running off from agricultural fields. This discourages the growth of algae and aquatic plants, which has the undesired effect of clogging ditches and hindering water flow. The shade provided by hedgerows also tends to hinder the growth of aquatic plants by reducing photosynthetic action. Some tree and shrub species, through the actions of micro-organisms living in the vicinity of their roots, also have the capacity to remove coliform and salmonella bacteria from watercourses (Mezzalira 1990; Urbinati 1994).

Prolific vegetation growth in watercourses is a frequent sight throughout the entire northeastern Veneto area. While no empirical evidence is available, it is extremely probable that the removal of hedgerows has contributed toward this phenomenon in addition the large quantities of fertilisers running off fields. In the absence of sound ecological land management methods, the prolific growth of vegetation in watercourses requires manual removal.

Atmospheric and Microclimatic Function

In larger atmospheric terms, the widespread removal of hedgerows decreases carbon storage and the absorption of carbon dioxide from the atmosphere. Locally, hedgerows have a moderating and microclimatic influence because of their effect on wind, temperature, and humidity (Mezzalira 1990; Urbinati 1994). This moderating influence produces significant benefits for agriculture, flora and fauna.

Climatically, wind is the driving force that controls microclimatic alteration in agricultural landscapes. A dense hedgerow reduces wind velocity for a distance up to 10-15 times the height of the hedgerow (Mezzalira 1990). This provides benefits such as reduced road dust and wind erosion, reduced evapotranspiration[36], and reduced breakage and damage to plant stalks, flowers and fruit from high winds.

Hedgerows also have a moderating influence on temperature in addition to their effect of reducing wind speed. The vegetation canopy of hedgerows absorbs energy, thus reducing daytime temperatures in adjacent areas. This radiation is then released during nocturnal hours and raises night temperatures. The result is a more even distribution of solar energy. The exception to this is situations when dense vegetation and calm winds produce temperature inversions, thus producing the risk of frost during shoulder seasons. During winter, hedgerows also tend to increase temperature slightly (Mezzalira 1990; Urbinati 1994).

It has been estimated that the benefits of hedgerows as windbreaks translate into anywhere from a 5 to 20 percent increase in agricultural productivity. Thus, the loss of agricultural production from land occupied by hedgerows, and adjacent shaded areas, (often given as a reason to eliminate them) is actually surpassed by productivity towards the middle of the field (Mezzalira 1990).

Regulation of Water Fluxes

The last vital function which hedgerow networks perform relates to the regulation of water cycles and land drainage. This was one of the most important and perhaps overlooked functions within the Lower Piave before wholesale removal of vegetation. In landscape ecological terms, hedgerows and associated vegetation help to regulate water fluxes in the landscape by intercepting

[36]Wind velocity and temperature both increase evapotranspiration. At certain critical levels, such as during summer dry spells, transpiration will cease as plants seek to conserve moisture. At this point however, photosynthesis is retarded and plant growth is curtailed. Thus a reduction of evapotranspiration can be beneficial to crop growth during certain periods (Mezzalira 1990).

water through root systems and pumping it vertically through plant growth and evapotranspiration. This action helps to produce drier soil and less stream flooding (Forman & Godron 1986).

Another effect of hedgerows is to directly intercept precipitation as a very thin film of moisture is retained on the vegetation canopy following rainfall. This may be absorbed back into the ground through plant stems, or released back into the atmosphere through evaporation if wind and temperature conditions are right (Urbinati 1994). The infiltration of water into superficial soil layers, aided by vegetation root systems and decaying organic material, also helps to retard the run-off of water into drainage watercourses and helps to recharge soil moisture and the water table (Mezzalira 1990). Although ground water recharge is not a concern in the Lower Piave, it is important in the upper Venetian Plain where aquifers are heavily exploited for drinking water and irrigation.

A system of hedgerows in a landscape also helps to physically control water runoff rates from farm fields. This is done by directly blocking or impeding water flow (Zanetti 1988; Burel & Baudry 1990; Burel *et al.* 1993). **By extension, this has an important effect on overall land drainage and allows one to relate the removal of vegetation with the worsening of drainage conditions in the Lower Piave area.** Burel *et al.* (1993) demonstrate how an integrated system of hedgerows play an important role in erosion and flood control in Brittany France. A system of parallel hedgerows planted on slopes, along with hedgerows planted on earthen banks along ditches, was designed to intercept water and soil particles running down field slopes. Field level drainage ditches also help to control water flow by either holding it or allowing it to percolate into superficial soil layers. The presence of ditches, which catch surface runoff, also leads to higher evapotranspiration (Forman & Godron 1986).

In the analysis of surface water drainage in section 6.3, the impacts of hedgerow removal were ignored by the Consorzio Basso Piave as a contributing factor toward increasing peak water flows after rainstorms. In light of the demonstrated role of vegetation in drainage regulation, combined with historical pumping capacity upgrades, **it is re-emphasised that widespread vegetation removal in the modern era has contributed significantly to worsening of drainage conditions.** This is backed up by anecdotal evidence where witnesses from the previous agricultural era of hedgerows confirm that filling of catchment basins once took many more hours. The former situation required lower technical and human efforts and resulted in reduced low level flood risks on the whole (Zanetti 1988).

Chapter 7: Interpreting Landscape Health

7.1 INTRODUCTION

This chapter represents the culmination of research where an interpretation of biophysical landscape health is produced for the highly governed landscapes of the Lower Piave. This is done through the integration of conceptual review, landscape history and land transformation, and findings from analysis of key landscape elements. This chapter contains three other sections. Section 7.2 provides a depiction and description of highly governed landscape interrelationships and linkages, as outlined in stage 5 of the methodology. This essentially ties together the analysis of the previous chapter, and is designed to illustrate how the highly governed landscape functions in terms of the interplay between key landscape elements. Section 7.3 provides an interpretation of biophysical landscape health based on the research and analysis of the previous 6 chapters. This consists of a broad definition of biophysical landscape health, a set of defining characteristics, and some criteria which can be applied to the measurement and assessment of health. **It should be emphasised that this conceptualisation of landscape health is place and context specific.** That is, while potentially applicable to other highly governed landscapes, the definition and characteristics are explicitly tailored to the biophysical and cultural context of the Lower Piave. The last part of 7.3 includes a summary of the measurability of health characteristics. Section 7.4 concludes the chapter by examining the characteristics of biophysical landscape health in relation to the perspectives used for its formulation.

7.2 CRITICAL HIGHLY GOVERNED LANDSCAPE INTERRELATIONSHIPS AND LINKAGES

Chapter 6 examined four key components of the Lower Piave highly governed landscape, including their evolution over time and important differences between conditions in the pre-modern and modern eras. This analysis permitted the discovery of some important linkages between different landscape components, and between biophysical landscape elements and human activities. This section completes the process started in Chapter 6 by tying everything together and illustrating the critical interrelationships in the highly governed landscape. The objectives of this particular stage are to summarise:

1) The most important landscape ecological linkages in the highly governed landscape as determined by the analysis in Chapter 6;

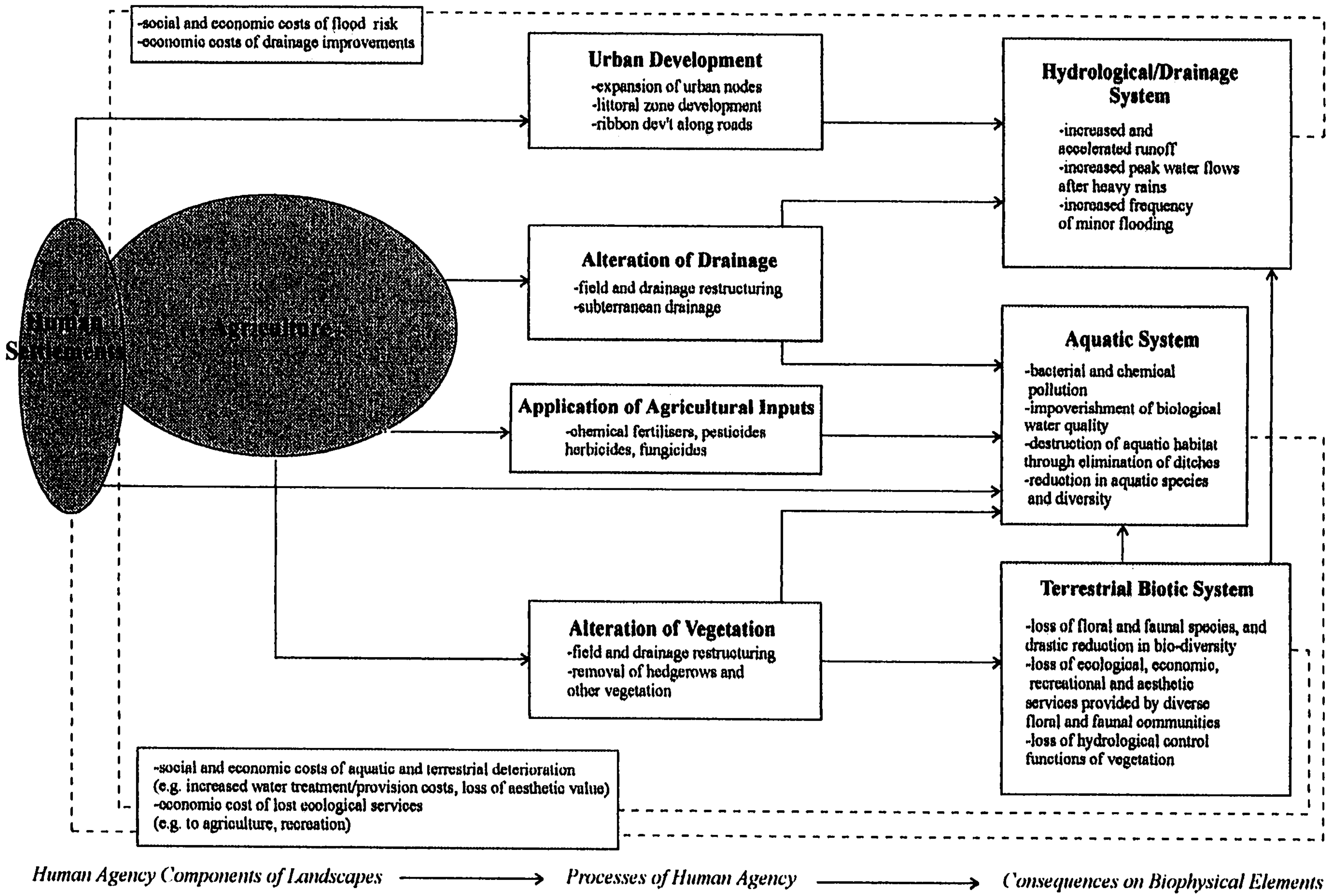
2) The principle actions of human agency on post-reclamation highly governed landscapes and their effects on biophysical landscape elements, and;

3) The circular feedback effects of human agency and human induced-change on landscapes.

Figure 7.1 summarises, in graphic form, the linkages and interrelationships in the highly governed landscape. The circular objects illustrate the principal **human agency** components of the landscape. The middle set of rectangles depicts the **processes of human agency**. The right hand side rectangles depict the key **biophysical landscape elements** identified in Chapter 6. The arrows extending from human agency processes indicate links between human processes and landscape elements. The main consequences of human agency processes are listed in the rectangles.

To begin with, increased urban development in the modern era has impacted the hydrological drainage system by accelerating and increasing runoff. Increased urbanisation has increased the total amount of paved area, and also added discharges from domestic and industrial uses. It has also been established that increased urbanisation and population growth has impacted the aquatic system through the introduction of bacterial pollution, nutrients, and most likely

Figure 7.1: Critical Landscape Interrelationships and Linkages



industrial pollution in localised areas. It was determined that urban areas in particular are responsible for proportionally higher discharges of nutrients than agricultural areas.

The alteration of land drainage in connection with landscape restructuring has affected both the overall surface drainage system, and aquatic biological systems. In Chapter 6, the impacts of vegetation removal and increasing installation of subterranean drainage on overall surface water drainage was demonstrated. Moreover, the widespread elimination of drainage ditches during the modern era has also eliminated a valuable aquatic ecotope that was characteristic of the pre-modern governed landscape. Drainage ditches at one time served as significant habitat for aquatic flora and fauna. Their elimination has severely impoverished aquatic habitat, and by extension the quantity and diversity of flora and fauna (Zanetti 1988).

The alteration of vegetation from the elimination of hedgerows has affected both aquatic and terrestrial biological systems through the loss of ecological and productive functions once provided by vegetation. The arrows extending from biophysical landscape element boxes indicate linkages between landscape elements. Both aquatic and hydrological/drainage systems are linked to terrestrial systems as landscape simplification has eliminated aquatic habitat and altered basin hydrology. The widespread removal of vegetation also has an expected impact on water quality given the positive effects of vegetation on water quality.

The ecological cycle is completed by the identification of feedbacks emanating from the consequences of human agency on biophysical landscape elements. In one feedback loop, the effects of land transformation on land drainage result in undetermined costs to society with respect to infrastructure works and low level flood risk. While it is inevitable that area inhabitants face high social and economic costs with respect to living in a highly governed landscape under permanent flood risk, changes to land drainage have undoubtedly increased economic costs to area residents. This manifests itself in increased infrastructure costs directed toward drainage and pumping capacity upgrades in order to decrease the frequency of minor flooding from 5 years to

10 years as specified by the *Piano Generale di Bonifica*. Unfortunately, the costs of landscape changes are not well understood, as it is difficult to estimate what infrastructure maintenance costs would have been without widespread landscape simplification.

The second feedback loop identifies the existence of possible economic costs and social consequences of changes to terrestrial and aquatic systems. Economic and social considerations of landscape health have mostly been omitted from this research for reasons mentioned in Chapter 1. However, it is still worth noting that there are probable, but as yet undermined, social and economic costs arising from human practices and landscape alterations. For example, what are the economic costs of water quality deterioration as a result of urban-based discharges, agricultural runoff and bacterial pollution? What are social costs associated with overall water quality deterioration and localised discharges of industrial pollution? Also, what are the effects on agriculture of the loss of ecological functions provided by hedgerow vegetation?

While not investigated in this research, it can be stated that these costs are mostly undetermined, as there is little acknowledgement that they exist. As a result, there are no environmental accounting mechanisms in place to measure these costs. The view that economic and social costs do exist is reinforced by cases where humans have compensated for landscape changes, or adapted to landscape changes, through external subsidies or substitutes. With respect to drinking water, it was noted how authorities now draw it from the upper Venetian Plain given the quality deficiencies in the lower plain. Therefore, there is no need to be particularly concerned with, or to even monitor, contamination of subterranean aquifers because of the existence of substitutes.

In the case of agriculture, chemical inputs now substitute for careful practices and landscape elements previously designed to take advantage of natural cycles and processes. Essentially, the loss of these ecological services through transformation is compensated for by the use of agricultural chemicals manufactured from relatively cheap petrochemical products.

Otherwise, many ecologically based agricultural practices would likely not have been phased out. Thus, while the cycle in Figure 7.1 suggests economic and social consequences, they are normally not accounted for in modern industrial society because of the ability of humans to substitute for lost ecological functions and resources. If the "sustainability" of human activities were given higher priority in the larger scheme of things, there could be more precise environmental accounting to quantify the economic costs of the ecological consequences of human actions.

Finally, the cycle of linkages illustrated in Figure 7.1 holds a couple of important implications regarding the issue of landscape health. Most importantly, the diagram illustrates the circular nature of linkages and interrelationships in the Lower Piave. This shows how the landscape is a system where the parts are interconnected and changes to one part of the system, or changes to external inputs to the system (either natural or human-induced), affect other parts of the system (or the entire system itself). **This reinforces the idea or belief that concepts of health should be holistic properties given that "everything is connected to everything else".**

The second implication is that the application of health concepts for both scientific inquiry (e.g. monitoring for landscape health), and landscape management (to ensure landscape health), must take into account the functioning of the landscape as a system or whole. That is, biophysical landscape health must not only be concerned with the individual biophysical and cultural elements within landscapes (e.g. soils, water, vegetation, human settlements and activities), but also with the linkages between these elements. These include interactions arising from both "natural" processes (e.g. climatic, geomorphological) and human agency processes (e.g. development, reclamation, land use activities) in the landscape.

7.3 INTERPRETATION OF BIOPHYSICAL LANDSCAPE HEALTH

This section defines biophysical landscape health for the highly governed landscapes of the Lower Piave, and is divided into three parts. The first part includes some key assumptions behind biophysical landscape health for these highly governed landscapes. The second part defines biophysical landscape health and identifies specific characteristics of health. This includes a discussion of each characteristic, including the measurability of each. Part three summarises the overall measurability of biophysical landscape health.

1. Basic Assumptions Behind Landscape Health

Some key assumptions behind landscape health are first stated because defining landscape health is a value-laden exercise, and is done within a specific cultural and landscape context. **The first assumption is that this view of biophysical landscape health is place and context specific as emphasised in the opening paragraph of this chapter.** Other assumptions are loosely classified as cultural and conceptual. Cultural assumptions have been derived primarily from what is known about the historical and cultural development of Lower Piave and Venetian landscapes, as outlined in Chapters 3 and 5. Conceptual assumptions mostly identify **values** which underpin landscape health. These values incorporate theoretical and cultural considerations, as well as biophysical landscape conditions.

From a **cultural** perspective, therefore, an interpretation of landscape health should accommodate the following considerations:

- In this part of the world, agricultural landscapes have been thoroughly manipulated and managed for a long period of time. Therefore land governance activities should be viewed as a normal cultural activity in this region.

- The successful perpetuation of traditional Venetian agricultural landscapes and their ecological functions over long periods of time (as recounted in Chapter 3), using simple methods passed from generation to generation, suggests that human manipulation of landscapes is not necessarily incompatible with the long term landscape health.

- Efforts to deal with flood hazards have traditionally focused on modifying the hazard or adjusting to losses. This philosophy is firmly entrenched in the system.

- A special form of land governance by humans, specific to the needs of agriculture, is inevitable in the long-term, as humans are not expected to abandon productive agricultural land that would otherwise revert to its former marsh state.

From a conceptual or "values" standpoint, the interpretation of biophysical landscape health assumes that:

- The ecological services once provided by traditional Venetian landscapes were valued by humans for practical reasons. From a health perspective, contemporary landscapes should also continue to provide practical benefits.

- It can be argued that the base reference landscape for biophysical landscape health assessment is the traditional Venetian agricultural landscape, as the "natural" landscape that emerged after the last period of glaciation has long disappeared from the Venetian Plain.

- Biophysical Landscape health is a holistic property that considers the functioning of the landscape system as a whole.

- Sustainability of both human activities and essential ecological processes is a vital component of biophysical landscape health.

- Human use of landscapes can be compatible with landscape health.

2. Conceptual Basis of Landscape Health

The conceptual basis of biophysical landscape health consists of a general definition and a series of characteristics. They have been derived through consideration of the series of questions outlined in Chapter 4 (see Stage 6). In short, biophysical landscape health for highly governed landscapes can be generally defined as:

A state or condition where human governance sustains a biophysical landscape character and structure that is relatively stable over time; accommodates traditional land uses; allows for balance both within and between biophysical and cultural system components; and maintains the ability of the landscape system to provide biophysical resources and processes beneficial to both humans, and other biological organisms.

An important characteristic of this definition is that a condition of biophysical landscape health includes the accommodation of traditional land uses given how, from an ecological standpoint, humans are an integral part of the landscape. In this case, agriculture is the most important cultural activity, so a condition of landscape health must exist in conjunction with this land use.

In connection with this definition are specific characteristics of biophysical landscape health. These have been derived primarily from consideration of the first series of questions outlined in Stage 6 of the methodology (see Chapter 4). From the literature, there are standard concepts or characteristics of system health which are applicable to biophysical landscape health. Elaboration of these characteristics follows their listing. This elaboration is important as it places each characteristic within the proper context of the Lower Piave study area, and surrounding highly governed landscapes.

Therefore, a condition of biophysical landscape health is interpreted as having a number of characteristics. In no particular order of importance, these include:

1) absence of disease and distress in biophysical landscape system components
2) absence (or mitigation) of environmental risk factors
3) sustainability
4) ecological resilience and stability
5) biological diversity
6) local equilibrium or balance between system components
7) landscape structural stability

1) Absence of distress and disease in biophysical landscape system components.

Within a biophysical context, there should be an absence of disease and distress factors attributable to human activities. From an ecological point of view, *distress* is derived from "stress" which refers to an external force, factor, or stimulus that either causes the ecosystem to respond, causes changes in the ecosystem, or results in ecosystem dysfunction (Rapport *et al.* 1985). In this sense, **distress refers to conditions of ecological dysfunction caused by human actions**. From an ecosystem health point of view, some indicators of distress include: bioaccumulation of toxic substances in soil, water and living organisms; increased incidence of disease in flora and fauna; reduction in species diversity; reduction in species populations; reduction in genetic diversity; eutrophication of waters; and reduction of habitat (Rapport *et al.* 1985; Rapport 1989b).

In the Lower Piave, distress arises from human land uses (agriculture especially) and associated resource demands (on nutrients, soil and water), physical restructuring of the land (drainage works, urbanisation), and the use of the landscape as a sink for wastes and deleterious substances (disposal of human, animal and industrial wastes). In this regard, the absence of distress characteristic is rooted in cultural land uses and human activities Problems of ecological distress are created when human activities create adverse impacts that cannot be absorbed or dissipated by biophysical systems.

A summary of potential distress factors in the Lower Piave is provided in column two of Table 7.1. The landscape elements in column one correspond to the elements examined in Chapter 6, with the addition of human "settlements". Most biophysical distress factors noted in the table have been referred to in the analysis of Chapter 6 and summarised in section 7.2.

Although social and cultural elements of landscape health have been excluded from this study, some distress factors related to "settlements" and "agriculture" are also included in the table for illustrative purposes. Distress factors cited under these categories serve to illustrate the importance of this characteristic from a "human as organism" standpoint. Along with other species in a landscape, humans are also affected by system distress factors and must make adjustments to compensate for system changes. Distress factors may accrue from a variety of causes and sources either internal or external to the system. Distress factors may overwhelm human adjustment mechanisms leading to dysfunction of human and cultural systems. Human elements which are vulnerable to system distress include overall human health and well being, aspects of community health (including related social institutions), and economic health. In short,

Table 7.1: Distress Factors in Lower Piave Landscapes

Element	Distress Factors (Indicators)	Measurement Criteria/Methods	Acceptable Thresholds
Agriculture	-loss of agronomic productivity -declining farm prosperity -stagnation of macro economic farming sector (Provincia di Venezia 1994b; Smit *et al.* 1998)	-analysis of trends using economic health indicators (e.g. net level of farm income, debt/asset ratios, costs of production, crop yields, farm returns, level of economic subsidies, etc.) (Smit *et al.* 1998)	-stable agronomic productivity -stable farm prosperity -stable macro economic farming sector
Settlements	-loss of community prosperity (e.g. income levels, increased unemployment) -decline in condition of physical infrastructure (e.g. roads, communication, essential services) -decline in social capital (e.g. family size and continuity, business continuity, rate of farm turnover, formal and informal community supports, number of voluntary organisations and participation rates) (Smit *et al.* 1998)	-analysis of trends using demographic, economic and social indicators/data	-stable or increasing community prosperity -stability in condition of physical infrastructure (e.g. roads, communication, essential services) -stability in social capital factors
Land Drainage	-ageing pumping and drainage infrastructure (Provincia di Venezia 1993; Consorzio di Bonifica Basso Piave 1991) -increasing inability to handle low level flood risk (Fassetta 1977; Consorzio di Bonifica Basso Piave 1991)	-age of pumping plant and equipment: -frequency of minor flooding -pumping capacity increases	-maximum acceptable life span of 50 years before retrofitting (Provincia di Venezia 1992) -ability of system to handle minor floods of 10 year frequency minimum (Consorzio di Bonifica Basso Piave 1991; Provincia di Venezia 1993)
Surface Water Quality	-eutrophication, bioaccumulation of toxic contaminants, organic loadings, excessive nutrient loadings, loss of aesthetic quality (Regione del Veneto 1993) -loss of species richness and composition, reduction in fish abundance (Karr 1981, 1991) -loss of species density and biomass (Loro *et al.* 1994)	-Index of Biotic Integrity (Karr 1981, 1991) -Extended Biotic Index (Loro *et al.* 1994; Turin *et al.* 1994)) -IRSA-CNR water quality classifications (Regione del Veneto 1993)	-IBI value greater than 55 (Noss 1995) -EBI of Class I or II (EBI value greater than 8) (Turin et al. 1994) -IRSA-CNR classes 1 and 1-2 (Regione del Veneto 1993)
Vegetation	-reduction of hedgerows/ hedgerow lengths (km per hectare) -reduction of hedgerow connectivity -loss of species and biomass -loss of landscape diversity	-comparison with hedgerow lengths/vegetation networks of pre-modern landscape state	-70 to 100 m of hedgerows per hectare (based on analysis from Chapter 6); or 250 metres per hectare as estimated by (Vianello & Vita 1994) -landscape diversity value >1.1; dominance value of 0.8 or less (Table 5.2)

"absence of distress" is also relevant from a "human as organism" standpoint, even though this aspect has been omitted from analysis.

Column three in the table indicates criteria for measurement of distress. Many of these have been referred to at some point during the study and are practical to apply given they were assessed in the landscape study. Most other methods of assessing distress usually involve an analysis of temporal trends to determine whether distress is increasing or decreasing over time. Criteria related to agriculture have been cited from an external source.

The fourth column identifies some existing thresholds for assessing distress levels. Most have been drawn from the analysis in Chapter 6, with the exception of those associated with cultural elements. Minimum distress thresholds associated with these factors are listed in terms of the maintenance of stability. The maintenance of current levels as acceptable thresholds is justified given the relatively high quality of life for residents of the area and northern Italy in general. It should also be noted that thresholds relating to vegetation are based on levels which existed in the pre-modern era. The assumption behind this decision is that vegetation characteristics and patterns in the previous era were much more conducive to overall biophysical health. This assumption is based on landscape ecological and integrity principles cited in Chapter 2. It might, however, be difficult to achieve these levels in a modern landscape context, so lower thresholds may be more practical.

2) Absence (or mitigation) of environmental risk factors.

In Chapter 2, it is mentioned that one of the approaches to assessing ecosystem health is to focus on the estimation of potential impacts of known sources of stress on receiving systems. This is also known as the "risk" approach (Rapport 1995b). In this regard, one can obviously conclude that the absence of excessive human-induced stresses on a landscape is a good thing.

Therefore, an essential condition of landscape health should includes the **absence** (or mitigation) **of environmental risk factors** in the highly governed landscape.

The idea of threats or risks to a landscape encompasses both natural and human phenomena. On the one hand, threats to landscape elements can be naturally occurring. For example, stress to floral and faunal communities can arise out of such things as climatic events, outbreaks of disease, and infestations of exotic species or insects (in the case of vegetation communities). For highly governed landscapes, however, the **absence of risk** characteristic refers to the risk of stress arising from human activities. According to this interpretation of biophysical landscape health, **risk factors** refer to conditions/human activities which create levels of stress harmful to humans and other organisms. In a Lower Piave context, these should be understood to mean:

- point sources of water pollution (e.g. poorly treated or untreated urban discharges)
- illegal industrial toxic waste disposal in watercourses
- poorly designed urban waste landfills
- industrial agriculture animal waste disposal
- excessive runoff of nutrients attributable to agricultural land use
- runoff of agricultural chemicals into watercourses
- bio-accumulation of toxic contaminants in soil, water and biota

In Chapter 6, these factors were cited as significant risks in the Lower Piave landscape. Ideally, a condition of biophysical landscape health would require the absence or mitigation of many of these risks. In cases such as illegal toxic waste disposal or illegal disposal of animal wastes, risks can be significantly reduced through stricter enforcement of existing laws. Other cases are more difficult to tackle and require structural adjustments, such as the shift to lower input or more sustainable agriculture. It should also be noted how the issue of risk factors overlaps with the previous characteristic as environmental risk factors are themselves sources of distress. This illustrates how landscape health characteristics are related to each other.

As for the precise evaluation of this characteristic within an overall landscape health assessment, one would require the identification of risk factors, knowledge of existing stress levels accruing from these risks, and understanding of the expected effects of different degrees of risk/stress levels. From this one may be able to identify acceptable thresholds of risk. Given the difficulty and complexity of such a task, combined with the absence of quantitative data, this study has gone only so far as to identify potential risk factors.

3) Sustainability

From a holistic "health" viewpoint, sustainability in a landscape context refers to the ability of a landscape system to maintain itself over a long period of time, and to adjust to periodic stresses and perturbations. That is, a healthy landscape is one where basic structures and processes necessary to ensure a condition of health are sustained over long periods. This definition, however, is regarded as being too broad and too systems oriented to be useful as a measurable characteristic of landscape health. Sustainability for these purposes should be understood as an **indicator** of landscape health, and in terms of sectoral activities rather than a particular landscape condition or state.

As an essential condition of landscape health, there are two angles of sustainability to consider. The first angle relates to the nature of the conduct of human activities in terms of specific economic activity sectors (e.g. resource extraction, agriculture). According to the classical definition, sustainability is a philosophy where human activities are conducted in a manner which allows them to continue indefinitely, or in the long term, while keeping external subsidies to a minimum. In a Lower Piave context, this aspect of sustainability has to be viewed in terms of the agricultural sector.

The sustainability of the agricultural sector could be assessed using a framework similar to Table 2.6 and applied in Chapter 6. This framework incorporates a wide range of sustainability considerations (e.g. social, economic, landscape), and lists specific criteria that can be evaluated vis-à-vis the agricultural sector (Table 7.2). The collective assessment of these considerations, as undertaken in Chapter 6, provides an overall picture of the sector's sustainability.

A more quantitative approach to the assessment of agricultural sustainability would be to develop a scoring system, and incorporate it into an index of agricultural sustainability. Under this approach, individual sustainability considerations would be ranked and scored in terms of how existing trends and characteristics approach agroecosystem health and sustainability guidelines.

Table 7.2
Framework for Assessing Sectoral Sustainability of Agriculture

Considerations:	Sustainability Guidelines
Farming Systems:	-proportion of farms using low input or sustainable agricultural techniques as defined in Table 2.4 -existence and number of certified biological agriculture farms
Landscape/ecological: 1. Vegetation	-presence of hedgerows and vegetation in agricultural landscape (minimum of 70 - 100 m of hedgerows per hectare)
2. Diversity	-high degree of land use and crop diversity -moderate level of landscape diversity with presence of closed fields and terrestrial natural areas such as wetlands (landscape diversity value around 1.1 or greater)
3. Risk factors	-absence or minimisation of risk factors specific to agriculture such as excessive fertiliser runoff, bioaccumulation of agricultural chemicals, excessive animal waste discharges on farm fields, waste discharges into watercourses
Economic: 1. Macroeconomic Viability	-sustainable/low input farming sector productivity and economic viability comparable to conventional agriculture sector
2. Microeconomic Viability	-farm productivity and profitability comparable to conventional agricultural farm

The second angle of sustainability relates to the overall state of biophysical landscape components in relation to a wider range of human activities, and their use of ecological resources such as air, water, soil, and biomass. In this sense, sustainability refers to the ability of the landscape to absorb stresses arising from human activities and its ability to continue to provide essential ecological services to humans and other biological organisms. The best way to approach the assessment of this aspect of sustainability is to determine the extent of *distress* conditions in key landscape elements. This process obviously borrows from what was proposed earlier regarding distress (Table 7.1), as the evaluation of distress also provides indications of the sustainability of human activities in relation to ecological resources. The overlap between sustainability and distress also illustrates how landscape health characteristics are related and assessment of one characteristic may also draw from the analysis of another characteristic.

4) Resilience and stability.

These two characteristics have been identified as qualities of ecosystem health and integrity in Chapter 2, and are closely related. Ideas of stability and resilience are usually discussed in the context of "natural" ecosystems, or natural terrestrial land units, and often in terms of vegetation communities; although these concepts are equally applicable to faunal communities within these entities as well. A resilient system is one that is able to recover to its pre-perturbation trajectory, or rate of change (e.g. successional path), relatively quickly after a perturbation (Noss 1995). "Natural" perturbations include such things are fires, disease, insect infestations and climatic events. The ability of an ecosystem to recover from these types of events is regarded as a form of ecological stability. While ecosystems are inherently unstable (as in constantly changing), a certain level of stability is characteristic of high integrity natural ecosystems (Noss 1995).

Despite their emphasis on "natural" ecological elements within landscapes, concepts of stability and resilience are also thought to have a large degree of relevance to communities and ecotopes within human-dominated highly governed landscapes. This is also true of vegetation communities, which are human creations in this particular landscape context[1]. With traditional Venetian landscapes, and most others across Europe, the vegetation for a long period of time before widespread modernisation of agriculture consisted of hedgerow networks. These networks are essentially vegetation communities as they are home to a wide variety of floral species. As with all forms of vegetation communities, these vegetation networks would normally be subject to natural disturbances (insects, drought). The resiliency of these hedgerow networks was demonstrated by their stability over long periods of time.

As noted earlier in the study, hedgerows were also subjected to human-induced disturbances such as cutting of wood and grazing from farm animals. In this context, vegetation communities had resiliency in the sense that they could recover from human disturbance. Or alternatively, intervention was planned and managed to ensure that these structures would continue to regenerate. Thus a form of stability occurred within the realm of human management of these structures. The resilience and stability of vegetation structures also promoted the resiliency of other communities given that these structures acted as habitat for other communities. Thus the survival of other communities was to a large degree dependent on the resilience and stability of vegetation networks.

Although an attractive concept, the measurement of resilience remains problematic. As stated in Chapter 2, its measurement would require some type of comparison between the recovery rates of stressed systems with unstressed systems. The number of communities and species present in landscape biotopes further increases the complexity of this task. For these

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[1]This discussion concerns itself primarily with the relevance of resilience and stability in relation to landscape vegetation structures, given the emphasis of this study. However, it must be stated that resilience and stability are equally applicable to a range of floral and faunal communities in a landscape.

reasons, there have been few developments in this area except for the identification of general resilience principles associated with landscapes. For example, it is generally accepted that simplified and impoverished landscapes, such as the cereal crop monocultures, are generally unstable and less able to resist disease compared to more diverse landscapes (Noss 1995). In this regard, it is possible to conclude that overall resilience levels in the Lower Piave have diminished in the modern era, given the dominance of cereal crop monocultures in fields largely devoid of any other vegetation.

Conversely, one possible option for measuring resiliency in highly governed landscapes lies with monitoring physical landscape structures that indirectly influence species resilience and stability. These include a variety of terrestrial natural areas in landscapes, such as aquatic biotopes and hedgerows. From a vegetation standpoint, ecological resiliency in agricultural landscapes is obviously related to the presence and stability of characteristic vegetation structures. In this regard, resilience can be indirectly assessed through the presence or absence of traditional vegetation structures and their stability over time. This can be monitored through reconnaissance and inventorying over time, and analysed in a manner similar to that which was carried out in section 6.5. In short, the stability (or lack thereof) of actual vegetation structures is an indirect indicator of the resilience and stability of associated communities. Measurement of stability and resilience in these terms should be considered in the absence of other practical means to measure resilience and stability.

5) Biological diversity and complexity.

Complexity refers to the number of species in the system, their abundance, and the number of interactions between species (Pimm 1984). Biological diversity is similar and refers to the variety and variability among living organisms and the ecological complexes in which they occur (Hunsaker & Carpenter 1990). These two variables are regarded as important predictors of stability and resilience - two other important measures of ecosystem health. Biological diversity is now seen as a primary indicator of both ecosystem health and ecosystem integrity (Costanza 1992b; Noss 1995).

Biological diversity is regarded as an important characteristic of biophysical landscape health for a number of reasons. Most important, perhaps, is the fact that human survival is linked to the appropriation of organic material provided by the growth and productivity of the multitude of organisms which inhabit the earth (Paoletti 1993a). Biological diversity helps to ensure that primary production from landscapes, including agricultural lands, is sustained. From a Lower Piave landscape perspective, one also accepts the vital role of biological diversity in current agricultural landscapes given they are home to a variety of organisms and communities (even in their current highly governed state), and are also the medium through which crop biomass is produced

Biological diversity also has an important role in sustainable and biological agriculture as discussed in Chapter 2. Soil biota and macroinvertebrate (insects) populations fostered by hedgerow vegetation corridors provide substantial benefits to low-input agriculture. These include nutrient recycling, organic decomposition and biological control of insect pests (Paoletti 1993a).

The measurement of biological diversity in agricultural landscapes has been successfully accomplished using macroinvertebrate species. These are commonly collected and monitored using soil cores, hand sorting and pitfall traps (Paoletti 1995). Through monitoring of invertebrate species using pitfall traps, Targa (1990) and Schirato (1991) have demonstrated how the presence of hedgerow vegetation and closed fields increases the diversity and complexity of pedofauna in agricultural landscapes. Paoletti (1993b) estimates that a northeastern Italian cornfield's soil could contain 200 to 450 invertebrate species compared to 300 to 500 in a less disturbed deciduous lowland.

Micro-level diversity studies of this nature can also be linked to the larger landscape/cultivation system in terms of whether its surface patterns are amenable to biological diversity. It is also possible to link biological diversity with overall landscape diversity as examined through some of the techniques used in Chapter 5. In this case, the expected relationship between vegetation and macroinvertebrate species means traditional closed field landscapes are expected to have a higher degree of biological diversity compared to contemporary open field landscapes of the Lower Piave.

6) Local equilibrium or balance between system components.

Ideas of equilibrium and balance have been brought up in discussions regarding ecosystem health and integrity. From an ecosystem integrity point of view, equilibrium in biophysical systems is said to represent the optimal operating point for that system. The optimal operating point is reached where organising thermodynamic forces (primarily the act of dissipating of energy) balance the disorganising forces of external environmental change. The example of a climax community has been mentioned as representing a *balance* between organising and disorganising forces in ecosystems (Kay 1991). The ability to maintain an optimum operating point when stressed, and to continue evolving and developing, indicates an ecosystem with integrity (Kay 1993).

The concept of balance has also brought up by Costanza (1992a & 1992b) with reference to the idea that a healthy system is one that maintains a proper **balance between system components**. In this sense, balance is complicated as there can be many possible biophysical balance issues in ecological systems and landscapes. For example, there are balances between predator and prey populations, community and population balances, hydrological balances, geomorphological balances (e.g. erosion and deposition), energy balances, and so on. In addition, there are also balance issues encompassing both biophysical and cultural aspects of landscapes, such as balances between resources and human use of resources (or sustainability issues).

Both these ideas are severely limited in a health and integrity context because they are general in nature and have not been operationalised, except in the case of perhaps vegetation communities. However, the idea of balance from an equilibrium standpoint holds a large degree of appeal in this study context. One important balance issue is human use of biophysical resources and its assessment is covered by the inclusion of sustainability as an important component of landscape health.

Another important balance issue in the Lower Piave is the relationship between water levels in the overall drainage basin, and elements affecting this variable. The importance of this balance issue was highlighted in section 6.3 of Chapter 6. It was also noted how drainage is basically related to the interaction between vertical landscape components (precipitation, soils, vegetation) and horizontal terrestrial elements including landscape vegetation patterns, field and drainage systems, and topography. This also includes human influences on topography as in the case of subterranean drainage installation.

It was also demonstrated how this issue has always been important in the Venetian Plain, where drainage control and management dates back to the Roman era. In traditional Venetian landscapes, land governance was designed to balance hydrological and terrestrial elements in order to maintain agricultural production. Within the broader landscape, one result was a balance between hydrology (runoff and drainage) and other landscape elements used to control it such as drainage ditches and associated vegetation. The benefit of this was relatively stable drainage and water flows during periods of regular and expected precipitation. This also extended to reclamation where mechanised drainage schemes were planned according to physical landscape characteristics. These hydrological balances were subsequently disrupted with the post World War II agricultural transformation.

In short, one of the requirements of a healthy landscape in this context is predictable discharges and water flows that can be managed by existing infrastructure. In turn, there are many landscape elements which play an important role in helping to regulate drainage. In this study, vegetation was identified as being an important element for controlling water infiltration and stabilising runoff. **Thus, an important balance issue concerns keeping surface water and drainage at stable levels by properly manipulating controlling landscape elements such as vegetation.**

In summary, the idea of balance and equilibrium has been identified as an important landscape property based on the relationship between vegetation and hydrology. However, it remains an elusive concept and can be difficult to pinpoint exactly. This research has identified a key balance issue, and its disruption was easily identified because of clear changes to drainage accruing from radical landscape changes. In other cases, however, relevant and important balance issues have to be identified as there are many possible balance issues in landscapes. Thus, the effective application of the concept first requires the identification of important balance issues in landscapes, followed by specific study and empirical investigations of relationships associated with these issues.

7) Landscape structural stability.

The last characteristic is referred to as **landscape structural stability**. This characteristic refers to the condition where basic structural characteristics of landscapes (e.g. vegetation and drainage systems) remain relatively constant over a long period of time. In the modern era, this condition is considered important primarily for cultural reasons, and applies to landscapes exhibiting many qualities of biophysical landscape health. This would have been more important in the pre-modern era given the important role these structures had on agricultural production. This characteristic is also measurable in most landscapes given the availability of topographic maps and air photos for most cultural landscapes in the Western World. It is possible to measure stability in this sense through natural features such as vegetation patches and corridors, and canals. It is also measurable through landscape indicators such as landscape diversity and dominance.

Landscape structural stability is considered important for a number of reasons. From an ecological perspective, the relevance of the stability idea has often been questioned given that ecological systems are constantly changing and therefore cannot be stable (Noss 1995). From a landscape perspective, however, the long-term stability of landscape structures has an ecological importance given that man made structures such as vegetation and drainage systems were once an integral part of the "natural" landscape in the Venetian Plain. Before widespread land transformation, hedgerow networks represented the vegetation component of the landscape in the almost total absence of the native ecosystems. Furthermore, ditch and canal systems represent(ed) important aquatic ecotopes which served as habitat for aquatic flora and fauna (Zanetti 1988) . While inevitable natural perturbations would normally afflict individual ecological communities (e.g. disease and insect infestations), long-term structural stability is important because it means that landscape structures will continue to provide habitat for other organisms and ecological functions valuable to humans.

From a cultural and heritage perspective, these landscapes also provide a link to the region's past and thus represent a valuable cultural and educational resource that will benefit tourism and learning. The importance of the learning aspect is highlighted by studies such as those by Schirato (1991) which examined the ecological significance of hedgerows. This is no longer possible in areas where vegetation structures have been eliminated. It is therefore advantageous to maintain the structural features of these landscapes for at least scientific and educational purposes.

There is also an aesthetic motivation related to the characteristic of landscape structural stability. The closed field landscapes still found throughout much of the middle and upper

Venetian Plain are visually pleasing to the eye, and some would perhaps argue, aesthetically preferable to the open field monocultures of the Lower Piave. While this is undoubtedly a value judgement, it is based on the personal preference of the author, and the precedent of the landscape which existed before widespread landscape simplification. In this respect, the flat, unvegetated and monotonous landscape of the Lower Piave is barren compared to the appearance of traditional Venetian landscapes.

3. Measurability of Landscape Health

One of precepts of developing a biophysical landscape health paradigm is that it should be reasonably practical to apply given sufficient resources for monitoring and assessment. Through elaboration of landscape health characteristics, mention was made on how to possibly monitor and evaluate these characteristics. Table 7.3 summarises the measurability of these characteristics, including methods to quantify characteristics. With appropriate modifications, depending on specific contexts, these characteristics are potentially applicable to other highly governed landscapes. Further discussion of the applicability of this biophysical landscape health concept to other cases is discussed in the concluding chapter.

The measurability of some landscape health characteristics is stated in terms of landscape level trends. This is designed to overcome some of the difficulty in measuring some of the characteristics outlined. However, this also arises out of the landscape chorological point-of-view that dominates this study. The monitoring of landscape level trends for what they tell us about landscape health is increasingly advocated because of the advantages of scale. In other words, while local health assessments tell us more about local conditions, landscape level measures can tell us about landscape health at a larger geographic scale based on what is known about landscape interrelationships.

Table 7.3
Measurability of Biophysical Landscape Health Characteristics

Characteristic	Measurable?	Methods of Measurement
1) absence of distress	-yes	-through identification and monitoring of distress factors in landscape (see Table 7.1)
2) absence of risk factors	-specific risk factors identifiable -difficult to measure and quantify risk levels without sufficient data and knowledge of expected effects of risk	
3) sustainability	-yes	-sectoral sustainability measurable using frameworks similar to that in Table 7.2 -overall sustainability of human presence in the landscape measurable through monitoring of ecological distress in biophysical elements (Table 7.1)
4) resilience and stability	-difficult to measure precisely	-can be indirectly assessed through monitoring of the stability and health of landscape vegetation patches and networks -monitoring of the stability of species populations in localised areas
5) biological diversity	-yes	-local and site specific measurement using traps and core samples -overall landscape state in relation to bio-diversity can be assessed by linking local diversity to overall landscape structural features and habitat characteristics
6) equilibrium or balance	-concept not operationalised except in the case of surface water hydrology	-surface water hydrological balance measured using runoff, basin coefficients and pumping capacity -comparisons with historical levels and landscape conditions
7) structural stability	-yes	-measurable through historical landscape analysis -is demonstrated when key landscape structures such as vegetation and drainage are maintained over time

It is also important to note that biophysical landscape health is also a measure of scale. In other words, landscape health is not absolute and exists in relative terms of more or less health. Issues of scale and degrees of landscape health have not been discussed in this study because it is primarily concerned with developing a concept rather than its application. Nonetheless, the issue of degree, and how to represent it, remains an important consideration when applying the biophysical landscape health concept.

7.4 CONCLUDING COMMENTS ON BIOPHYSICAL LANDSCAPE HEALTH

In summary, biophysical landscape health for *highly governed landscapes* can be summarised as a condition where human governance sustains a landscape which is free from distress and risk factors, is stable over time, allows for balance between key system components (even if heavily governed by humans), and allows for provision of biophysical services essential to both humans and other organisms. While the definition emphasises biophysical aspects of landscape health, a crucial assumption behind this definition is that traditional land uses and land governance are not incompatible with "healthy" landscapes.

The inclusion of **resilience and stability**, **biological diversity**, and **equilibrium**, reflects the importance of maintaining biophysical landscape processes, which provide benefits to humans and other organisms in the highly governed landscape. Other characteristics are more culturally oriented as they concern themselves with the interplay between human land use and biophysical systems. Issues of **sustainability**, **distress and risk factors** are also directly associated with economic, social and human health concerns, but were not examined in any depth given the emphasis on biophysical landscape health. **Landscape structural stability** reflects the fact that landscape features can be valued for other than productive or monetary considerations.

Another point to raise in this summary is that many landscape health characteristics are interconnected. In particular, sustainability is connected to distress and risk factors; distress is related to risk factors; resilience and stability depend largely on biological diversity; and diversity is related to landscape structural stability. The interconnection between characteristics is not viewed as redundancy, but as inevitable given how landscapes themselves are complex entities where many elements are interrelated and interconnected.

The last point to be discussed concerns this perspective of landscape health in relation to other perspectives of "health" from which this research has drawn upon. That is, how do these components of biophysical landscape health match other perspectives examined in the literature review?

This study has borrowed substantially from the field of ecosystem health and its related concepts. In terms of ecosystem health, there are universal aspects which are widely applicable to a variety of environmental situations (e.g. absence of disease and pathology, absence of environmental risk factors, resilience to stress, diversity and complexity). Many of these are also applicable to landscapes, and in some way have been incorporated into this concept of health. The measurement of these parameters is summarised in Table 7.3. The use of landscape level measures is a way of dealing with a major shortcoming of the ecosystem health concept where many characteristics are difficult to measure (e.g. homeostasis/self organisation, diversity/ complexity, vigour/scope for growth).

Conversely, this health concept differs significantly from ecosystem health in that it takes a multi-dimensional perspective compared to established ecosystem health practice as cited in the literature. With ecosystem health, there has been a tendency to focus on a particular approach, such as assessing distress, risk, or resilience/counteractive capacity. This concept proposes that a variety of health characteristics be monitored and assessed.

Moreover, this concept of landscape health differs substantially from the only existing concept of landscape health as proposed by Ferguson (1994 & 1996). He defined landscape health in terms of self-regulation or as the operation of homeostasis, where the system tends to return toward the functional levels from which it was displaced by system disturbances. This study has not adopted anything from this conception of landscape health, simply because of the difficulty in measuring "self regulation" aspects of landscapes.

Similar to health, definitions of ecosystem integrity have focused on diversity and the ability of a system to continue the process of its own self-organisation. Again, this is difficult to measure in a practical sense and has limited application of ecological integrity only as a general concept . However, the biological diversity aspect of integrity has been adopted in this definition of landscape health. As alluded to throughout this study, biological diversity is a requisite of integrity. It is also measurable on a local scale as illustrated by examples from northeastern Italian literature. Local scale assessments can then be related to larger scale landscape composition and structure.

In contrast, the field of sustainability appears to be more easily definable and quantifiable compared to something as complex as "health". For example, it was possible in Chapter 6 to examine the conduct of agriculture and farming systems from an overall sustainability perspective as specific methods associated with sustainable agricultural systems have been identified. In this regard, some might argue that sustainability represents a more appropriate and useful framework/paradigm to examine issues of environmental quality compared to "health", which has been severely criticised in certain quarters (as noted in Chapter 2).

However, sustainability is not normally viewed as an approach to assess "health", but rather as a means to assess the conduct of specific human activities in relation to the land and resource base. Sustainability is also a good indicator of "distress" in terms of the use of biophysical resources. For this reason, sustainability of human activities is considered a requisite of health, and has therefore been included as an indicator of biophysical landscape health.

Landscape ecology is also not normally viewed as a framework to measure the health or quality of landscapes. "Health" is a state or condition, while landscape ecology is a scientific discipline. For this reason, there are no landscape ecological concepts or terms among the seven characteristics of biophysical landscape health with the exception of landscape structural stability. However, it is concluded here that landscape ecology is the most valuable disciplinary framework related to biophysical landscape health.

In the first place, the chorological perspective of landscape ecology identifies structures, patterns and relationships in landscapes which affect many characteristics of health. For example, it has been emphasised throughout that there are landscape structural features which promote biodiversity, an important characteristic of landscape health. Also, various terrestrial landscape components and structural features have an impact on both water quality and hydrological balances. Therefore, the discipline of landscape ecology is an important vehicle with which to investigate and identify relationships that have an important bearing on biophysical landscape health.

The second important contribution landscape ecology makes is to provide methods to indirectly measure some of the characteristics of biophysical landscape health at the landscape scale. These methods were referred to throughout the discussion in section 7.3 and included in Table 7.3. As mentioned previously, one of the shortcomings of other health paradigms is that they are difficult to measure, especially at larger spatial levels and geographic scales. Through the identification of horizontal spatial structures and patterns, which correlate to individual characteristics of health, it is possible to make some sort of landscape health assessment at the landscape level. This is an extremely important consideration if we are serious about assessing biophysical landscape health at larger spatial scales.

In conclusion, biophysical landscape health for highly governed landscapes borrows heavily from the field of ecosystem integrity and the concept of sustainability in terms of specific characteristics of health. However, it appears that landscape ecology provides the means for a great deal of the practical application of the biophysical landscape health concept. Therefore, a landscape ecological perspective, with its associated methods, appears to be a more logical framework for conducting biophysical landscape health research and assessment. This is a significant finding given how the main objectives of this research stemmed from the "health" paradigm(s), and it was initially thought this would make the most significant contribution to biophysical landscape health.

Chapter 8: Conclusions

8.1 INTRODUCTION

From the outset, this research sought to explore and develop the concept of biophysical *landscape health* as a practical paradigm for *highly governed landscapes*. The primary motivation for this research was that there currently appears to be is no suitable paradigm with which to evaluate these landscapes from a biophysical "health" perspective. The two central research objectives were to: 1) determine the conceptual, cultural, and ecological bases of "health" for the highly governed landscapes of the Lower Piave area; and 2) to develop a suitable interpretation of biophysical landscape health for the highly governed landscapes of this area.

This concluding chapter wraps up the study by examining some key contributions and implications of this research, as well as some important issues stemming from the study. This chapter is divided into three remaining sections. Section 8.2 first summarises the main study findings and conceptual contributions of this research. This is followed by an evaluation and discussion of these contributions in terms of the principal research objectives and other broader conceptual issues. Section 8.3 evaluates methodological contributions and other methodological issues. The last section concludes by summarising some key implications of the study, including potential applications, management issues and additional lines of research concerning the broad issue of landscape health.

8.2 RESEARCH CONTRIBUTIONS

1. Summary of Study Findings and Research Contributions

This study has revealed a number of important findings with respect to the nature of landscapes and the state of biophysical landscape health in the Lower Piave. It has also produced a conceptual definition of biophysical landscape health for landscapes not currently covered by existing environmental paradigms. The main research contributions are now summarised as a prelude to the evaluation of study accomplishments relative to the initial research goals and objectives.

The first important contribution of this research is the Lower Piave landscape study and its key findings found in Chapters 5 and 6. Chapter 5, in particular, illustrates the creation of a highly governed landscape, and depicts subsequent land transformation using a combination of empirical and descriptive methods. The landscape study of Chapter 5 is probably most significant for the fact that it is one of few empirical accounts of this process, and the first within the context of northeastern Italian reclaimed areas. The only other example of historical landscape change is provided by Giacomin (1992), who examined landscape heterogeneity and evolution over a period of about 170 years for a rural comune near the city of Padua. Chapter 5, however, is unique from the standpoint that it is the first attempt to examine land transformation within an overall perspective of "health". Therefore this study is significant in how it relates land transformation to biophysical health and integrity principles.

From a landscape change standpoint, extensive land transformation of the Venetian Plain began during the Roman era and the conversion of the entire plain to agricultural landscapes was completed by the end of the 19th century. The 20th century brought widespread transformations to both the Venetian Plain and the Lower Piave area. During the early 20th century, the Lower Piave area was transformed to a **highly governed landscape** when its extensive marsh areas were reclaimed to agricultural land. Another phase of land transformation occurred with the modernisation of agriculture following World War II. In this phase, landscapes were simplified to accommodate the needs of modern agriculture.

The post-reclamation highly governed landscape represented the base reference point for biophysical landscape health. A comparison between the post-reclamation pre-modern landscape, with the modern contemporary landscape, was the basis for the comparative analysis in Chapter 6. Four basic landscape elements were examined in this analysis (agriculture, drainage, water quality, and vegetation). The analysis of agriculture revealed how it evolved from a predominantly subsistence form, to a modern and highly productive system within the span of a couple of decades after World War II. From a sustainability standpoint, however, current farming systems are heavily dependent on agricultural chemicals and technological inputs. Earlier farming systems were judged to be more sustainable over the long term because of their reliance on a closed system in terms of energy, materials, and nutrients.

Earlier farming systems also maintained a biophysical landscape structure that conformed to many landscape health characteristics cited in Chapter 7. This was primarily because piantata and closed fields cultivation systems dominated the landscape. There were also more diverse cropping and cultivation patterns. In former times, hedgerows and piantata provided valuable ecological and productive functions to farmers. This ensured that these structures would remain; thus maintaining a from of landscape structural stability. This stability promoted biological diversity, production of natural resources, and provided an aesthetically pleasing landscape.

The stability of cultivation systems, and their characteristic structures, also helped to maintain drainage balances in the pre-modern agricultural landscape. This study has demonstrated how a stable surface hydrological system is an important component of landscape health, given the economic costs of maintaining reclamation, and the need to control low level flood risk. A renewed balance between terrestrial landscape elements and overall land drainage should a key management goal for these landscapes.

Chapter 6 also pointed to an important linkage between human land use and water quality distress. There was substantial evidence to link water quality distress with urban wastewater discharges and agricultural fertiliser runoff. A necessary condition of biophysical landscape health is the mitigation or elimination of water quality distress factors.

The most important contribution of this study is the definition of biophysical landscape health for highly governed landscapes. This represents a new and more appropriate environmental paradigm for a landscape that bears little resemblance to its condition before widespread human modification, and which is unlikely to return to even a remote resemblance of that state because of human commitment to continued governance. This is a significant contribution because there appears to be no other framework or paradigm suitable for assessing the biophysical state and condition of these landscapes as a whole. This definition, and corresponding characteristics, also sought to overcome some of the conceptual and practical limitations of existing paradigms when looking at highly governed landscapes.

Conceptually, a condition of biophysical landscape health exists when human governance sustains a biophysical landscape character and structure that is relatively stable over time, allows for balance between biophysical system components, is free from damaging human-induced distress and risk factors, and which continues to provide biophysical functions essential to both humans and other organisms. Specific characteristics of biophysical landscape health include absence of distress, absence of risk factors, sustainability, resilience, biological diversity, equilibrium and balance, and structural stability. A necessary condition of landscape health is that these characteristics exist in conjunction with traditional human land governance and land uses. This is a key condition given that humans and their activities are part of cultural landscapes, and land governance activities are an inextricable part of highly governed landscapes.

2. Evaluation of Research Contributions and Accomplishments

This part of the conclusion examines study accomplishments and contributions in terms of whether initial research goals and objectives were successfully achieved. The first research objective was stated as the determination of the conceptual, cultural and biophysical bases of health. As to this objective, it can be concluded that these bases were successfully outlined within the contextual boundaries set out in section 1.3 of the opening chapter.

In the first place, the landscape history identified historical patterns of land governance, and concluded that the practice of intensive land governance is a normal cultural activity in the region dating back to the Roman era. The assumption throughout this study was that these cultural attitudes played a role in influencing reclamation and subsequent landscape simplification in the modern era. Reclamation is viewed largely as a positive human achievement despite elevated economic and social costs. In light of these attitudes, a high degree of governance seems inevitable for these landscapes in the foreseeable future.

Furthermore, the study identified agriculture and human settlement as the traditional cultural activities with the most direct bearing on biophysical landscape health. A more recent phenomenon is coastal urban development for recreation. Human activities are highly inter-linked with biophysical landscape elements as illustrated in Figure 7.1. The study also demonstrated the impacts of these activities on biophysical systems, and by extension, biophysical landscape health.

From a cultural perspective, human, social and institutional aspects of health were omitted from the study for practical reasons stated in section 1.3. However, these aspects are significant from the standpoint that comprehensive landscape health assessments require the consideration of both biophysical and cultural issues. Thus, further lines of research into landscape health could include the definition and examination of cultural parameters of landscape health. These include social, economic and human health issues, and their examination could be conducted using a framework of human ecology. When combined with the biophysical characteristics derived from this research, a comprehensive landscape health concept and assessment framework is in place. This can be further complemented with the inclusion of risk factors facing humans in these highly governed landscapes. Risk to humans and property from flooding is an especially serious issue in this area, and requires further research and investigation in light of the paucity of data concerning this matter.

Moreover, there are additional cultural aspects not examined here that play an important and indirect role in biophysical landscape health. Specifically, institutional factors either directly or indirectly influence human land and resource use patterns (e.g. national, regional, and provincial government departments, agencies, and legislation; European Union legislation and directives). Another line of additional research can be the investigation of the effect and/or role of various government institutions toward a variety of landscape health issues such as landscape change, landscape health assessment, and landscape rehabilitation.

From a biophysical landscape health perspective, the most significant biophysical elements identified in this analysis are overall land drainage, surface waters, and vegetation. While common to most landscapes, the selection of these specific elements was largely related to the specific biophysical nature and cultural land uses of the Lower Piave. Land drainage is the most significant biophysical aspect given most of the Lower Piave is below sea level. This aspect is closely interrelated to agricultural land use and vegetation patterns in the landscape (and hence the reason for their selection as other critical landscape elements). Vegetation is also normally a standard feature of either horizontal and vertically oriented landscape analysis. The quality of surface waters was selected as a variable for analysis as it is closely related to agriculture and settlement aspects of the landscape. Further discussion on methodological considerations regarding landscape elements is found in the next section.

The second, and most important, research objective was also fulfilled with certain inevitable limitations. The conceptual definition of biophysical landscape heath is thought to outline a new paradigm with which to examine and evaluate the biophysical health of Lower Piave landscapes, and similar highly governed landscapes. The development of this paradigm has borrowed significantly from existing fields and disciplines; each of which have their own limitations regarding application to assessing overall landscape states.

The landscape health paradigm as developed is regarded as having a number of significant strengths compared to existing paradigms and notions of health. First of all, it represents a more appropriate paradigm for *highly governed landscapes*, as traditional norms of healthy land states are not applicable to these cases. The vision of a "natural" ecosystem (e.g. pristine ecosystem or wilderness), or even modified natural ecosystem (e.g. a grassland subject to periodic grazing by domestic animals; or a forest landscape matrix of both intact and logged areas), does not provide a relevant standard of health to assess highly governed landscapes; nor even the landscapes of the Venetian Plain where the last vestiges of wilderness probably vanished during the middle ages, and the original climax vegetation was basically eliminated during the Venetian era. **In this context, health is not predicated on the degree of human disturbances as its principles are designed to cover landscapes that are intensively utilised and manipulated.** While tailored to the Lower Piave area, the basic framework of health characteristics is also applicable to other landscapes fitting the description of governed or highly governed. This point is expanded upon in section 8.4.

Another strength is that biophysical landscape health is broken down into a set of seven defining characteristics that constitute a basic framework of biophysical landscape health. This framework is comprehensive, in that it attempts to include a variety of characteristics to assess the state of the biophysical landscape. Characteristics are also measurable to varying degrees given a commitment to sufficient monitoring, data collection, and information processing. This basic framework is useful from a resource and landscape management perspective, as detailed sets of indicators can be developed for each characteristic, and subsequently applied to collectively determine overall states of landscape health. Although health parameters were outlined under various characteristics in Chapter 7, application of biophysical landscape health assumes further development of suitable suites of indicators.

While the idea of "health" itself is holistic in nature, the view of health from this study is an attempt to produce a biophysical health concept that is holistic, comprehensive and reasonably practical to apply from a resource manager's perspective. This is contrasted with ecosystem health, for example, which tends to take a particular approach toward assessing health such as monitoring distress, counteractive capacity and risk factors. The landscape health concept is also distinct from sustainability in that it takes a more comprehensive biophysical landscape perspective rather than a sectoral (e.g. agriculture) and distress perspective (effect of human activities on biophysical resources). The health concept developed also contrasts with the existing landscape health paradigm as described by Ferguson (1994 & 1996). Ferguson's approach is little more than an extension of the self-organisation and non-equilibrium systems view of health to the landscape level, and is limited in that it has not been operationalised to any degree.

Alternatively, there are some inevitable limitations with the landscape health concept developed here. A significant limitation is that some characteristics of general system health, such as *balance* and *equilibrium* are not easily operationalised. They must be viewed in terms of specific landscape elements and relationships (in this case vegetation and hydrology). Other characteristics such as *risk levels* and *resilience* are also difficult to measure because of high complexity, data limitations and our limited knowledge of many ecological relationships, including the cause\effect relationships between stresses and organisms.

These particular limitations also point to future lines of research and monitoring related to biophysical landscape health, such as finding better ways to monitor some health characteristics rather than using indirect landscape level measures as specified here. This is not a contradiction the a previous statement regarding measurability, but recognition of the fact that biophysical landscape health is a complex concept to implement. Furthermore, additional research into the effect of human induced stresses on populations and communities is needed to quantify risk arising from human activities. This type of knowledge is noticeably lacking in this particular context.

Another limitation of the landscape health concept relates to cultural perceptions of biophysical landscape health. While considerable effort was made to include cultural criteria in the definition of landscape health, the research has not fully explored regional cultural perspectives on landscape health. Specifically, what are contemporary cultural perspectives of landscape health, and what do local people feel about landscape health? This would require further extensive research, and is essentially another line of research that can be pursued. It also means that local and regional perspectives of landscape health may differ from this perspective. This last statement highlights the point that health is ultimately a value judgement and there are, or likely to be, widely differing perspectives on health.

These limitations also highlight the difficulty of implementing landscape health investigations. This research conducted its own form of landscape investigation for the purposes of obtaining a general idea regarding the biophysical conditions of the Lower Piave, and for identifying relevant biophysical landscape health issues. A full application of the biophysical landscape health concept, as defined here, would require a substantial commitment and allocation of resources to undertake the required monitoring, data collection and analysis.

8.3 METHODOLOGICAL REVIEW

Methodologically, this study has made some important contributions and raises some additional important methodological issues. These are now briefly reviewed and discussed. One significant methodological contribution has been the successful application of the horizontal (chorological) landscape point of view, and some of its associated concepts (heterogeneity) and measures (diversity, dominance), to the specific landscape context of the Lower Piave area. This was accomplished through the qualitative and quantitative analysis of land transformations in Chapter 5. This represents a significant accomplishment because the landscape analysis was based on the unique perspective of both land cover and cultivation systems. This contrasts with other studies cited which have focused on land cover patches and land use. Measures of landscape diversity and dominance calculated in Table 5.2 are comparable to values cited from studies using primarily land cover data (Turner & Ruscher 1988; Medley *et al.* 1995). This illustrates the feasibility of using cultivation systems for chorological landscape analysis.

Moreover, Chapter 5 represents a model for larger scale historical geographical and landscape analysis. This method could easily be applied to a wider geographic area given the topographic map base that is available for all of Italy. A real constraint, however, is the sheer amount of data that must be interpreted and digitised to produce a quantitative landscape change picture for a larger area. As mentioned previously, Giacomin (1992) provides another model for historical land use and landscape transformation. In comparison, Giacomin focuses on a smaller spatial area and examines both landscapes and cropping patterns. A longer-term historical analysis is made possible through the use of the *Mappa Catastale Napoleonico*, 1807-1809. This series of land use and land cover maps was produced by the Napoleanic regime, which controlled northern Italy Prior to Austrian take-over in 1814-15.

Another methodological contribution is the identification of key landscape linkages and interrelationships in the form represented by Figure 7.1. The significance of this contribution is twofold. First of all, it represents a holistic way of approaching biophysical landscape analysis and management. This method emphasises how the landscape is a system comprised of inter-linked biophysical and cultural elements and processes. The circular nature of the system stresses how different variables influence and affect other parts of the system. It also shows how changing human practices and influences can throw the system out of balance, with subsequent consequences for humans which often necessitate further interventions or substitutions by humans.

Second, the depiction of the landscape as a system indicates that a holistic landscape approach is a prerequisite to successful landscape health related assessment, planning and management. This conclusion may seem obvious given the preponderance of this idea in contemporary literature. It is nonetheless a significant observation, given that this type of thinking does not appear to have entered resource and environmental management in the mainstream Italian context. A more holistic and landscape health approach would undoubtedly represent an improvement on current information gathering and management efforts which appear mainly sectoral, and which have done a poor job of integrating elements within the system.

The landscape analysis from Chapter 6 also raises a number of methodological issues that are now discussed. The first issue relates to the landscape elements selected for analysis in Chapter 6. These elements reflected biophysical conditions and predominant human land uses. However, a significant limiting factor for the number of elements considered was the availability of information. Significant information constraints were noted in Chapter 4 and ultimately limited what could be included for analysis. For example, a significant omission may be soils and their related dynamics. Available literature suggests that soil degradation (e.g. erosion, salinisation) is not a significant problem in this region, with the exception of normal rates of sheet erosion and sediment transport which fill in ditches and canals over time. However, there also appears to be insufficient monitoring and data with respect to suspected problems of bioaccumulation of toxic substances in soils and aquatic sediments. Therefore, while soil is usually considered an important factor in landscape ecology from both a vertical and horizontal point of view (Vink 1983; Forman & Godron 1986), it was omitted from this study because of the preceding considerations.

This example also raises the point of how landscape study itself, in terms of the elements and relationships selected for study, can vary widely. For example, land drainage is perhaps the most important biophysical consideration in the Lower Piave because of land reclamation and the depressed topography. However, drainage would probably assume a lesser importance in landscapes with different topographical characteristics. Moreover, while there are universal biophysical components in landscapes (e.g. air, vegetation, fauna, water, soil, and landforms), specific elements and relationships selected for study can be dictated by a number of factors. These factors include the biophysical character of the landscape, the emphasis and boundaries of the investigation, study methodology, and the training and disciplinary perspective of the researcher. Even the study of similar landscape relationships can be viewed under different perspectives. This is illustrated by the example of how Bas *et al.* (1990) took a different point of view when examining the relationship between landscape structure and hydrology.

Historical and contemporary information limitations also affected the depth of analysis of individual landscape elements in Chapter 6. This issue was cited at certain times in the analysis and was especially true of water quality. Prior to the modern era, there was no monitoring of water quality so some conclusions were deduced from available evidence. A perfect example is the conclusion that the Piave river was probably less polluted in the pre-modern era given water was withdrawn for human consumption during the first few decades of the century. In the modern era, comprehensive monitoring of water quality distress is restricted to larger watercourses, where the entire grid of smaller watercourses should be monitored for distress. Similarly, the analysis by the Consorzio di Bonifica Basso Piave (1995) focused on nutrients and runoff while largely neglecting the issue of agricultural chemicals.

In summary, these information limitations provide an indication as to further monitoring and research needs, as it is clear that thorough landscape health assessments require comprehensive data and information. This study used existing data, which was not explicitly collected for this purpose. Four main information requirements have been identified for proper biophysical landscape health assessments. These include:

- research into historical states of biophysical landscape elements;
- comprehensive monitoring of the main biophysical components of the landscape;
- more thorough study and monitoring regarding the effects of human activities on critical landscape elements;
- more accounting for the feedback effects of human alteration of the landscape.

Having this information will not only permit more comprehensive biophysical assessments, but will also assist with management to promote landscape health.

8.4 RESEARCH IMPLICATIONS AND CONCLUDING COMMENTS

The previous two sections have examined the principle conceptual and methodological contributions of this research, as well as discussing issues related to these contributions. This last section concludes the study by summarising the key implications stemming from this research. These concern potential applications of the landscape health concept, methodological and management implications, and future lines of research.

One important implication of this research relates to possible applications of the biophysical landscape health paradigm. The concept developed was place and context specific, in that it was tailored to the highly governed landscapes of the Lower Piave area. The nature of these landscapes is that they are reclaimed, intensely cultivated, and subject to a high degree of manipulation in the form of controlled and mechanised drainage. By extension, this paradigm and its characteristics should also be applicable to other similar "poldered" landscapes that rely on mechanised drainage. This also relates to the question posed in Chapter 1, as to the nature of highly governed landscapes and what are other examples of highly governed landscapes.

This paradigm is also considered to be applicable to Venetian Plain landscapes under which Lower Piave agricultural landscapes were initially modelled on after reclamation. While not subject to intensive drainage works, Venetian Plain landscapes are similar in that they are intensely cultivated agricultural landscapes. They have also been subjected to the same process of simplification during the post World War II era, although not to the extreme degree as the Lower Piave. Furthermore, all of the defining characteristics of biophysical landscape health are considered to be potentially applicable to these landscapes.

This then raises the point that the basic characteristics behind this paradigm can conceivably extend to most agricultural systems throughout Europe which share many biophysical similarities to Venetian Plain landscapes (both in a modern and pre-modern context). For example, man made structures such as planned drainage grids and hedgerows are typical of most European landscapes. Hedgerows in particular have been constructed, managed and removed by farmers over the centuries in response to political, technological and economic changes in society (Burel & Baudry 1989). As with Venetian landscapes, the English landscape has been characterised by a high degree of human governance over the ages of recorded history, and has been called "the result of 10,000 years of human achievement and failure"[1]. Another case is provided by the landscapes of Brittany, France, which reflected not only human colonisation patterns, but conscious planning of vegetation and drainage to control water fluxes (Burel *et al.* 1993). Moreover, the problem of landscape simplification in response to changing agricultural practices is common throughout most of Western Europe in the post W.W.II period (Hoskins 1988; Burel *et al.* 1993; Ihse 1995)

Thus, biophysical landscape health (or variations of the basic idea), and associated methods, is thought to be potentially applicable to other cases which bear a similarity to the Lower Piave land laboratory. This may also include forms of North American agricultural landscapes, which in certain cases fit the criteria of being "governed" or "highly governed" as defined in this dissertation. Possible examples of North American highly governed landscapes are arid irrigated landscapes and prairie landscapes intensely utilised for agriculture. In these cases, abandonment

[1] From: C. Taylor in Hoskins': "The Making of the English Landscape" (1988).

of cultivation would lead to a relatively quick conversion to former landscape states (or a close resemblance to the former ecological state). This is in contrast to eastern North American agricultural landscapes (e.g. southern ontario), where abandoned farmland requires considerably more time to revert back to its once forested state.

A significant methodological implication arises from a conclusion arrived at in the discussion at the end of section 7.4. Briefly, it was concluded that while biophysical landscape health borrows heavily from ecosystem health and sustainability, landscape ecology is the most important conceptual and disciplinary framework for application of the biophysical landscape health concept. On balance, landscape ecology appears to be the most appropriate base from which to conduct biophysical landscape health research and assessment.

The analysis of Chapter 6 provided an assessment of the state of certain biophysical elements as well as the evolution and practice of agriculture in the Lower Piave. While the boundaries of the study excluded institutional and management aspects of health, the study provides some important indications regarding management for landscape health and rehabilitation of Lower Piave landscapes. These deserve brief mention for information purposes, and also represent further lines of research into landscape health.

The conduct of agriculture is a vital consideration for landscape health given it is the dominant land use activity and has produced a number of stresses. The most serious issue with respect to the conduct of modern agriculture is its intensive use of chemical inputs and the consequences to landscape health and possibly human health. The movement toward more sustainable or low input agriculture, and ultimately biological agriculture, would constitute progress toward solving this problem.

Along with changes to the conduct of agriculture, the rehabilitation of vegetation is the other main key to landscape health and should be given top priority from a landscape management perspective. The replanting of hedgerow corridors in areas which do not impede agriculture (e.g.

along roadways, overpass grades, property lines, collector canals/ditches, the sides of dikes, on abandoned lands and relict areas, and around rural farm buildings), would help to reasonably simulate the traditional landscape of the past and provide a substantial boost to sustainable agriculture and overall landscape health.

The rehabilitation of vegetation would also contribute to the stability of land drainage, which is a key requirement of landscape health. Despite commitment to infrastructure improvements, the stability of drainage will remain an important issue because of the movement toward subterranean drainage. In addition to vegetation replanting, the solution to this problem is to be more selective with the installation of tubular drainage in order to balance the needs of production with the needs of efficient drainage. Installation should be avoided in areas that will not substantially benefit from its installation, such as in areas with better draining soils (sands and silts) and topography more favourable to natural land drainage. Subterranean drainage should continue to be installed in areas with very poor drainage characteristics, such as with heavy clay soils and in especially flat and low lying areas (Consorzio di Bonifica Basso Piave 1991).

And finally, management for landscape health requires some consideration of urban and settlement issues given the impact of urban discharges on water quality and issues associated with flood hazards. The first priority should be to upgrade sewage treatment capability to full primary and secondary chemical treatment in larger urban communities, and to connect remaining urban nodes and industrial areas to wastewater treatment facilities. Sewage treatment is currently inadequate in most communities and is likely to worsen with the expected expansion of urban areas and industry (Consorzio di Bonifica Basso Piave 1991).

In the longer term there must be a more coherent development policy as urbanisation directly conflicts with water quality, drainage and natural hazards management. With respect to flood hazards, a more rational and alternative approach would be to use zoning to permit development only in areas less prone to flooding. While this type of policy does not resolve the risk problem, it would prevent more people and property from being placed at risk, and is preferable to the current policy which consists of doing nothing and bearing the costs of flooding.

The last issue to be summarised concerns further lines of research and study concerning the landscape health issue. This is a significant issue because landscape health is a complex and multi-faceted concern, of which only one aspect has been dealt with in this research. While further lines of research have been suggested throughout this chapter, it is perhaps a fitting conclusion to the study to summarise this aspect in a concise manner.

From a conceptual standpoint, perhaps the most important line of future research and study is to expand the comprehensiveness of the concept. This would involve expanding the boundaries of the landscape health concept to include cultural aspects such as social, economic and human health issues, similar to what was briefly introduced in Table 7.1. Another important addition to the landscape health concept is the inclusion of risk factors arising from natural hazards. This issue was excluded from the study, but is nonetheless important because of the elevated flood risk facing inhabitants in the Lower Piave. In both cases, separate levels of inquiry are required from qualified experts using the appropriate disciplinary frameworks such as human ecology and risk analysis.

Further development of the landscape health concept would also be enhanced by research into contemporary cultural perceptions of landscape health. While effort was made to incorporate the cultural development of landscapes and their governance into this research, it is possible that local and regional perspectives of landscape health differ from this conception of health, which is undoubtedly influenced by the researcher's North American academic training. The survey and incorporation of local values of health represent another line of research, and would help to eliminate outsider bias and perspective.

A second area of inquiry concerning landscape health is the application of expanded landscape health parameters and methods to full-scale assessments of landscape health.

Compared to this focused study, undertakings of this nature usually belong in the realm of government given the large financial and technical resources required for this. Larger scale and more comprehensive assessments also require better and more extensive monitoring and information. Some of the information requirements also point to key areas of further research including more thorough study regarding the cause and effect relationship of human activities on critical landscape elements, and more accounting for the feedback effects of human landscape alteration. Another important area of further investigation is regarding the matter of how to monitor and measure certain health characteristics such as resiliency, balance and equilibrium.

A third area of additional enquiry lies with management aspects of landscape health. A key element of the landscape health issue is rehabilitation of degraded landscapes and management strategies to promote healthy landscapes. While some management implications arising from the study have been briefly mentioned, this represents a separate and extensive level of enquiry that encompasses both technical and institutional aspects of management. The technical aspects of landscape rehabilitation and management are well established in the region. However, there is room for analysis of institutional factors relating to landscape health assessment and rehabilitation. This includes study of the effect of present institutional structures on current landscape health, and ways to re-organise existing structures and policies to better promote healthy landscapes.

In closing, this study has examined a regional case of humans transforming the land in an attempt to meet social and economic objectives. On a global scale, human population growth and development patterns are progressively eliminating remaining natural environments and expanding the extent of cultural landscapes. Alternative methods are needed to assess the state and condition of these landscapes as comparisons with "natural", or undisturbed landscapes, becomes increasingly irrelevant. This study makes a contribution by proposing a new landscape health paradigm appropriate to highly governed landscapes, and potentially applicable to a variety of cultural landscapes. Perhaps the most important feature of this paradigm is that it considers biophysical landscape health in terms of landscapes which have been extensively altered by humans and are subject to an intense degree of manipulation by humans. Furthermore, the basic ideas behind the biophysical landscape health concept can be an important tool in planning and management to ensure that cultural landscapes are "healthy", and continue to provide a sound and stable habitat for humans and other organisms.

Glossary of Terms

(Latin or Italian terms in italics)

Actus - A Roman measure applied in centuriation. One *actus* measured 35.52 metres in length (Caravello & Giacomin 1993; Provincia di Venezia 1994a).

Alta Pianura - Literally translated as "upper plain", and commonly used as a geographic reference to the portion of the Venetian Plain above the *risorgive* belt.

Arbusto - Strictly defined as a woody plant with branches to its base, and not exceeding a height of 5 metres.(Zanetti 1995a). Term is also commonly used as an adjective for low hedgerows, and a vegetation classification category for shrubs and bushes.

Bassa Pianura - Literally translated as "lower plain", and commonly used as a geographic reference to the portion of the Venetian Plain below the *risorgive* belt.

Biological Diversity - Refers to the variety and variability among living organisms and the ecological complexes in which they occur (Hunsaker and Carpenter 1990).

Campo - Literal Italian term for field, but also used to refer to cultivated areas.

Colmata - Controlled fluvial landfill system of reclamation using sediments carried by rivers (Bondesan *et al.* 1995). Under this system, an area to be reclaimed is first contained by dikes and then flooded by sediment laden waters over a number of years. Sediment deposition gradually raises the level of the land thus allowing it to drain naturally.

Comune - Italian term for municipality or municipal subdivision. The Italian State hierarchy consists of regions, provinces and comuni. The comune is the lowest form of administrative subdivision and is centred on different levels of urban entities ranging from large cities to towns. The comune also covers surrounding rural areas and other smaller urban nodes.

Conduzione con Salariati - A classification of agricultural enterprise used for census purposes; characterised by the use of salaried workers to perform farm operations (ISTAT 1991a).

Conduzione Diretta - A classification of agricultural enterprise used for census purposes; characterised by direct cultivation by landowners (ISTAT 1991a).

Consorzio - Literally translated as "consortium" or "bureau". Usually used in reference to either land reclamation bureaus (***Consorzi di Bonifica***), or water supply agencies (***Consorzio Acquedotto)***.

Consorzi Idraulici - Bureaus of hydraulic (or drainage) restructuring; Common in the 19th century before widespread land reclamation was possible through mechanised pumping (Fassetta 1977).

Hedgerow - A linear vegetation structure/corridor that lines or separates fields in agricultural landscapes. Within a Venetian Plain context, it can consist of a complex structure of mature trees, bushes *(arbusti)*, and herbaceous plants, to a more simple structure of rows of bushes or coppice woods.

Heterogeneity - Landscape ecological term which applies to both the spatial and temporal aspects of landscapes. Refers to a condition of dissimilar or diverse ingredients or constituents forming a landscape (Forman & Godron 1986).

Homeostasis - Systems term referring to the maintenance of a steady state in living organisms by the use of feedback control processes and mechanisms (Pimm 1984; Costanza 1992a).

Hydraulic Reclamation - Reclamation or works designed to facilitate the flow of rivers and drainage of low lying land in order to reduce flood risk.

Landscape - A heterogeneous land area composed of interacting ecosystems dispersed throughout the area (Forman and Godron 1986).

Mesophilic - Plant species favouring moderate climatic and light conditions (Zanetti 1995a)

Mezzadria - A repressive system of property and productive relations with feudal era origins; entrenched during the Venetian era, and persisting widely until the middle of the 20th Century. The system was based on the rural peasant returning roughly one half the quantity of produce gained from farming activities, in return for the right to farm or occupy agricultural lands.

Piantata - Refers to a cultivation system of fields separated by rows of trees married with grape vines. Trees served the purpose or holding the vines. Also refers to the individual rows of trees and vines.

Prealpi - Literally defined as the "Pre-alpine" belt, or section of the Venetian Plain immediately preceding the Alps. Also translated as a piedmont or foothills belt.

Provveditori - A Venetian Republic body established during the second half of the 12th century, and responsible for planning and overseeing hydraulic restructuring and reclamation (Cosgrove 1990).

Risorgive - A hydrological belt of frequent spring and stream formation which forms the dividing line between the upper Venetian Plain and lower Venetian Plain. Geologically, this belt is formed by the meeting of the permeable substrates of the upper plain with the more impermeable clay substrates of the lower plain (Regione del Veneto 1988; Cosgrove 1990).

Set Aside - Term adopted by European Community Agricultural policy. Refers to the practice of removing land from agricultural production to meet supply management goals; as in the "setting aside" of agricultural land (Commission of the European Communities 1993).

Terraferma - Originally a Venetian term which referred to the territorial hinterland of the Venetian Republic which stretched from the Adriatic to the Alps, and from the Po river to the eastern limits of present day Friuli region (Cosgrove 1990).

Torrente - Literally translated as "torrent" and describes a river whose flow is highly variable according to season and extreme precipitation events.

Trevigiano - Once used to refer to the territory around the city of Treviso, and which now roughly corresponds to the area of the current Province of Treviso.

Udometric Coefficient ***(coefficiente udometrico)*** - Coefficient of runoff expressed in litres/second/hectare. It is the main measure used to calculate both drainage basin runoff, and the pumping capacity needed by individual pumping stations in reclaimed areas (Fassatta 1977; Consorzio di Bonifica Basso Piave 1991).

Venetian Plain - Loosely defined as the northeastern arm of the Northern Italian Plain extending from the Berici Hills in the Veneto to the eastern end of the Friuli region.

Xerophilic - Plant species favouring arid soils (Zanetti 1995a).

Zona Lagunare - Corresponds to the belt illustrated in Map 1.1, and which comprises the low-lying coastal belt of the Northern Italian Plain. Prior to widespread land reclamation and coastal armouring in the 20th century, this belt represented the interface between land and sea. The terrain consisted of deltas, lagoons and sandspits which would be continuously evolving due to sediment deposition from rivers, and erosion and sediment transport from sea currents (Walker 1967; Ortolani 1967).

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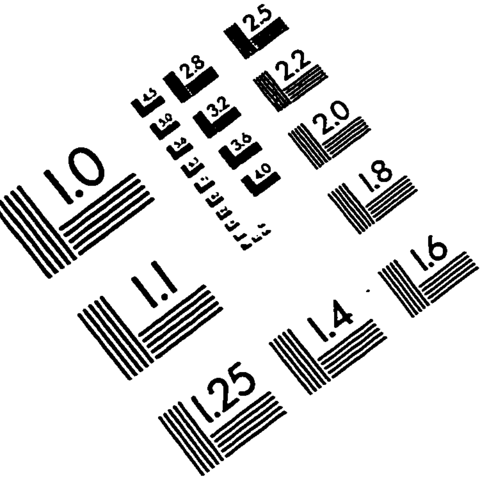
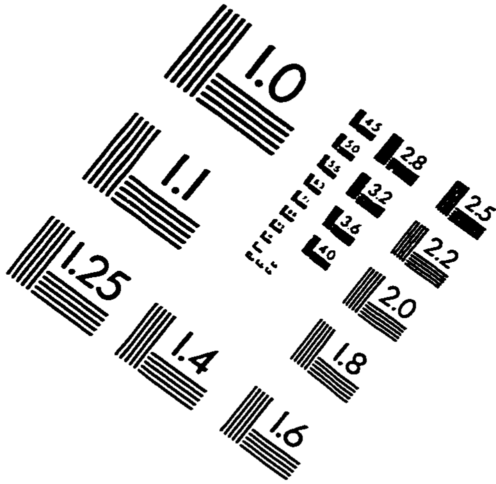
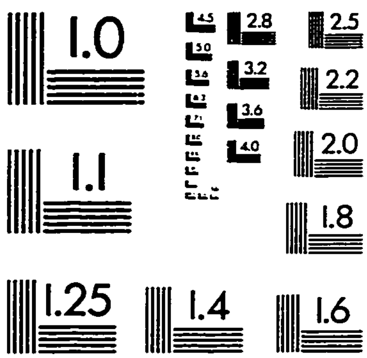
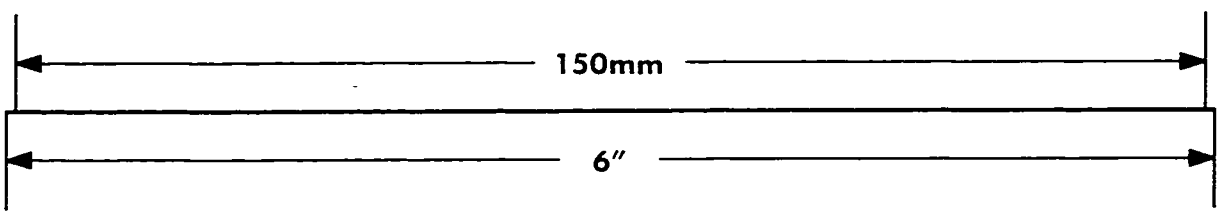
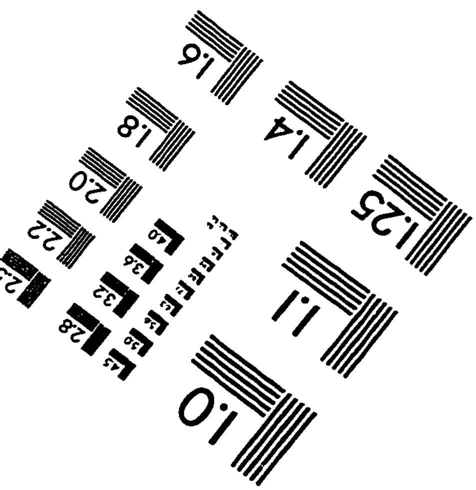
IMAGE EVALUATION TEST TARGET (QA-3)

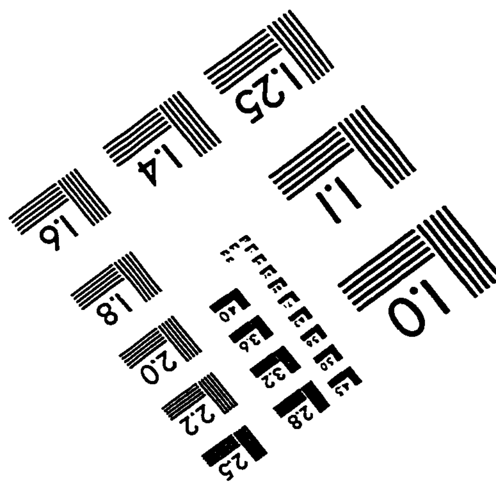












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