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INTEGRATED APPROACHES FOR EVALUATING DEVELOPMENT STRATEGIES IN RURAL AREAS.

CASE STUDIES FROM ITALY AND CHINA

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Tesi di dottorato di
GIUSEPPINA SICILIANO

Matricola 955281

Coordinatore del dottorato
Prof. GIAN MARIA ZUPPI

Tutore e Cotutore del dottorando
Prof. GIUSEPPE MUNDA E
Prof. MARIO GIAMPIETRO

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ABSTRACT

Abstract

The objective of this thesis is twofold: (1) to investigate the synergies arising from the implementation of multi-scale and multi-criteria approaches in the evaluation of rural development policies (RDP); (2) to explore the impacts and trade-offs of rural development strategies called for by official policies in two selected case studies located in Italy and China, respectively. The thesis argues that multi-criteria and multi-scale approaches can be combined to provide a useful framework with which to structure an integrated analysis of RDP in order to assess their effectiveness in achieving sustainability goals across scales.

The analysis is performed by selecting and evaluating multidimensional criteria, which represent the main goals of development policies in the areas of study (increasing the income per capita, reducing the human pressure on the environment, improving the social condition of the rural population). Moreover, multi-scale analysis is performed to define boundary conditions and trade-offs for future local development.

The first case study refers to a rural area of Italy and deals with the analysis of the sustainability of different agricultural practices in the presence of soil degradation and the Common Agricultural Policy (CAP) effectiveness to support sustainable agriculture at the farm level. The methodology used in this case is the Social Multi-Criteria Evaluation (SMCE). The second case study refers to a selected rural area of China and deals with the analysis of the effectiveness, in sustainability terms, of rural-urban migration strategies at the household and village levels. The methodologies used in the Chinese case are both Social Multi-Criteria Evaluation (SMCE) and Multi-scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM).

The case studies relate to the main strategies of the official RDP in Italy and China, the support of sustainable agriculture and the reduction of rural-urban gap respectively.

The use of the two methodologies appears to be very significant to capture both the multidimensional and multi-scale aspects of the Rural Development Policies analysed and to generate several sets of “view-dependent” representations of rural systems that are useful for trade-off assessments.

Keywords: multi-criteria analysis, societal metabolism, multi-scale analyses, sustainability, rural development, agriculture, rural-urban migration strategies.

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LIST OF ABBREVIATIONS

AHC	Agglomerative Hierarchical Clustering
ARSIA	Regional Agency for the Development and Innovation in Agriculture
BAU	Business as usual
CAP	Common Agricultural Policy
CAS	Complex Adaptive Systems
CBA	Cost-benefit analysis
CCP	Conventional Cultivation Practices
COL	Colonized Land
CRES	Centre for Soil Erosion Studies
EEA	European Environmental Agency
EEC	European Economic Community
EOAL	Ecological Overhead Available Land
ET nopw	Energy Throughput not Paid Work
ET pw	Energy Throughput paid work
EU	European Union
EU	European Union
FAO	Food Agricultural Organization
GI	Gross Income
GI nopw	Gross Income non-Paid Work
GI pw	Gross Income Paid Work
GI sub	Gross Income Subsistence
GLASOD	Global Assessment of Soil Deterioration
GSP	Gross Saleable Production
ha	Hectares
HA agr	Human Activity Agriculture
HA hc	Human Activity Household Chores
HA ind	Human Activity Industry
HA l&e	Human Activity Leisure and Education
HA nopw	Human Activity non-Paid Work.
HA po	Human Activity Physiological Overhead

HA pw	Human Activity Paid Work
HA sub	Human Activity Subsistence
HA t&s	Human Activity Trade & Services
HC	Household Chores
HEPA	High External Power Agriculture
HFC	Hourly Fuel Consumption
HH	Household
HLC	Hourly Lubricant Consumption
hp	Horse power
HRS	Household Responsibility System
ICP	Integrated Cultivation Practices
ISTAT	Italian National Bureau of Statistics
JRC	Joint Research Centre
Kg	Kilograms
L&E	Leisure and Education
LEPA	Low External Power Agriculture
LIAP	Land in Agricultural Production
LIAP	Land in Agricultural Production Subsistence
LML	Land Management Law
LNAP	Land Not in Agricultural Production
LP	Labor Productivity
MCDA	Multi-Criteria Decision Analysis
MEDALUS	Mediterranean Desertification and Land Use
MEFA	Material and Energy Flow Analysis
MJ	Mega Joules
MuSIASEM	Multi-scale Integrated Analysis of Societal and Ecosystem Metabolism
NAIADE	Novel Approach to Imprecise Assessment and Decision Environment
NAP	National Action Programs
NGOs	Non-Governmental Organizations
NPC	National People’s Congress of China
OCP	Organic Cultivation Practices
OFcr	On-farm crops

OFlv	On-farm livestock
OFin	Off-farm industry
OFts	Off-farm trade and services
PC	Principal Components
PCA	Principal Component Analysis
PO	Physiological Overhead
POFaq	Partially off-farm aquaculture
POFag	Partially off-farm agriculture
POFagr+o	Partially off-farm agriculture + others
POFo	Partially off-farm others
PW	Paid Work
Q	Quintals
RDP	Rural Development Policies
RLCL	Rural Land Contract Law
RMB	Renminbi (people's money of China)
RUSLE	Revised Universal Soil Loss Equation
S	Surface area
SC	Soil compacting
SEL	Local Economic Systems
SIIC	Shanghai Industrial Investment Corporation
SMA	Social Metabolism Analyses
SMCE	Social Multi-Criteria Evaluation
sq. km	Square Kilometers
SUB	Subsistence
t	Tonnes
TAL	Total Available Land
TET	Total Energy Throughput
TGI	Total Gross Income
THA	Total Human Activity
TRRDP	Tuscan Region Rural Development Plan
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCOD	United Nations Conference On Desertification

INTRODUCTION

Introduction

Rural areas play a significant role in providing a variety of services for human well-being. These services can be included in the provision of environmental amenities, landscape preservation, rural employment, food security, cultural heritage, as well as recreational and tourist destinations (OECD, 2001; FAO, 1999; Caron and Le Cotty, 2006; Zander et al., 2007). The increasing multidimensional role of rural areas in providing multifunctional services, in addition to their traditional role as food supplier, is now worldwide recognized.

Rural development policies (RDP) at the global, national and regional levels are informed by the need to provide rural areas with a better standard of living in an environmentally and socially sustainable way, across different scales (individual, household, communities, regions and countries). However, while sustainability of rural areas is a globally recognized objective, the way to achieve it in terms of interventions differs considerably according to geographical areas, as well as political and economic conditions. This is the case for example of Europe vs. China.

On one side, in Europe, according to the Council Decision (2006/144/EC) on community strategic guidelines for rural development, "agriculture continues to be the largest user of rural land, as well as a key determinant of the quality of the countryside and the environment". Sustainable agriculture and organic production is then recognized by EU regulation as one of the crucial interventions for the achievement of a sustainable management of rural areas. Moreover, it considers local rural development as a strategy to reduce the out-migration of rural people especially in less favored areas. Therefore, within the European RDP, the Common Agricultural Policy (CAP) plays a determinant role in achieving sustainability in rural areas and reducing out-migration.

On the other hand, China, as a less industrialized country, is facing, in addition to the environmental protection of rural areas, increasing rural-urban gaps in income, poverty and living standards. As a consequence, while the European RDP considers the abandonment of rural areas as a challenging aspect of rural development and tries to avoid it, the Chinese government sees the "urbanization" of rural people as a strategy to achieve rural development.

What does seem clear is that the current policy context, at the global, regional and local levels, will increasingly demand forms of policy analysis applicable to the more complex goals and institutional structures for rural development. Thus, assessing policy performance across different scales and dimensions of sustainability is a key element in the evaluation of development policies. Recognitions of the importance of the scale in the analysis of human-environment interactions have grown considerably over the past decade. The Millennium Ecosystem Assessment recognises the key role played by multi-scale and multidimensional approaches to meet the needs of decision makers related to the interaction between ecosystem services and human well-being. Moreover, it states that assessments should not be done at a single global scale but should also account for processes of ecosystem change and human impacts at other scales, for example by including the scale of individual communities (MA, 2005).

This aspect leads to the general political and research interest to seek for evaluation frameworks capable of dealing with multidimensional and multi-scale aspects of development, and in specific rural, local and/or regional contexts.

Based on the above considerations, and after an explanation of complexity theory applied to the analysis of coupled social-ecological systems, this thesis addresses the question to what extent and under which conditions rural development policies improve the living condition of marginal population and favor the environmental protection of rural ecosystems.

This is done by using integrated approaches based on the implementation of multi-criteria and multi-scale methodologies.

These methodologies are applied for the evaluation of RDP in two distinct case studies.

The first one refers to a rural area of Italy and deals with the analysis of the sustainability of different agricultural practices in the presence of soil degradation and the CAP effectiveness to support sustainable agriculture at the farm level. The methodology used in this case is the Social Multi-Criteria Evaluation (SMCE).

The second case study refers to a selected rural area of China and deals with the analysis of the effectiveness, in sustainability terms, of rural development policy interventions, mainly based on the process of "urbanization" of rural people at the household and village levels. The methodologies used in the Chinese case are both Social Multi-Criteria Evaluation (SMCE) and Multi-scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM).

The case studies relate to the main strategies of RDP in Italy and China mentioned above, the support of sustainable agriculture and the reduction of rural-urban gap respectively.

The use of the two methodologies appears to be very significant to capture both the multidimensional aspects of the Rural Development Policies and to understand the functioning of rural systems in terms of their interactions with the external environmental and economic contexts and across different levels of analysis.

In fact, the MuSIASEM approach makes it possible to describe the human-environment interactions establishing a coherent relation among variables and across scales. This characteristic allows one for the representation of the typical hierarchical organization of complex systems. The SMCE is a robust normative approach for the analysis of the multidimensional aspect of sustainability issues to support the decision-making process. The integration of the multidimensional aspect, together with the multi-scale characteristic of social-ecological systems, represents in my opinion a step forward in the design of an integrated framework for analysing coupled social-ecological systems from both normative and descriptive points of view.

For the above reasons, the Chinese case study represents an attempt towards a combination of the two models, demonstrating that both normative and descriptive analyses are fundamental to reflect the complex nature of social-ecological interactions.

In both cases the application of multi-criteria and multi-scale approaches allows for:

(i) the identification of the impacts and trade-offs of RDP related to different dimensions of analysis (economic, environmental and social);

(ii) the evaluation of RDP effectiveness in achieving sustainable development goals.

However, only in the Chinese case study the same analysis is performed at two different levels establishing a coherent relation among the variables using a bottom-up procedure, i.e. from rural households to the village level.

The work presented here is the result of various research efforts undertaken in the last 3 years.

The first case study refers to an elaboration of data previously collected in a field work undertaken during work experiences at the National Researcher Council of Italy, Centre for Erosion Studies (CRES), within the activities of the project "Development of methodological tools for the study of erosion phenomena, application to a study area" and published in 2008 in the Journal of Environment, Development and Sustainability.

The second one refers to data collected during a field work of four months in China, partially in Shanghai and partially in Chongming island, from October 2008 to January 2009.

Note on the structure of the thesis

This thesis has three main parts.

1) The first part consists of chapters 1 and 2 and refers to: (i) a general definition of Complex Adaptive Systems (CAS) and of their main characteristics focusing, in particular, on the description of rural systems as CAS; (ii) an introduction of various models used to realize integrated analysis of sustainability, making a distinction between normative and descriptive models; (iii) the definition of rural development policies (RDP) and the analysis of the relationship between RDP and sustainability. They also provides a description of the main aspects that characterize RDP in Europe, Italy and China. After that, it presents the basic concepts and rational of the methodologies used for the integrated analysis of RDP sustainability, i.e. the Social Multi-criteria Evaluation (SMCE) and the Multi-scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM), together with an explanation of the reasons why they have been chosen.
2) The second part of the thesis consists of chapter 3 and 4 and deals with the presentation of two empirical case studies which refer to selected rural areas of Italy and China respectively. Chapter 3 shows how SMCE can be used for an integrated analysis of sustainability at the farm level considering simultaneously economic, environmental and social indicators. It also provides an analysis of the effectiveness of RDP, in particular related to CAP interventions, on the diffusion of sustainable agricultural practices (organic agriculture) in the area under investigation. This chapter refers to a published paper in an international refereed journal.

   Chapter 4 shows how a combination of multi-criteria (SMCE) and multi-scale (MuSIASEM) approaches can be useful for the identification and the analysis of trade-offs between the social, environmental and economic spheres related to RDP interventions both at the household and village levels.

   Both chapters are organized in three main parts: (i) the description of the case study area and the problem under investigation; (ii) the theoretical presentation of the concepts and methods used for the analysis; finally (iii) the presentation of results and main conclusions.
3) The third part consists of chapter 5 which presents the general conclusions related to the entire thesis.

1. RURAL SYSTEMS AND COMPLEXITY: THE NECESSITY TO PERFORM MULTIPLE SCALE INTEGRATED ANALYSIS

Summary
This chapter after a general definition of Complex Adaptive Systems (CAS) and of their main characteristics focuses on the description of rural systems as CAS and on the need to perform multi-scale integrated analysis to better represent the complex nature of such a systems.

1.1 Rural systems as Complex Adaptive Systems (CAS)

According to the definition of J. H. Holland a Complex Adaptive System (CAS) "is a dynamic network of many agents (which may represent cells, species, individuals, firms, nations) acting in parallel, constantly acting and reacting to what the other agents are doing" and more "the overall behavior of the system is the result of a huge number of decisions made every moment by many individual agents" (Holland, 1995). Examples of complex adaptive systems could be those of the human organism, the nervous system of a human, but also ecosystems, the biosphere and whole economies. The main aspects that characterize complex adaptive systems are four: heterogeneity, nonlinearity of patterns, hierarchical organization, and flows. *Heterogeneity* relates to the diversity of the components of the system, which, through *nonlinear* interactions become organized *hierarchically* into structural entities (Levin, 2000). These entities interact by the exchange of *flows* (e.g. flows of energy, matter, information, money). These aspects of complex adaptive systems give us the opportunity to analyze them such as a family of related entities, in which each entity is characterized by essential features and simultaneously "to explore through simplified models the properties that all such systems have" (Levin, 2000). A simplified way to analyze complex adaptive systems, characterized by a vast amount of data, is through the use of categories, trying to represent the intrinsic hierarchical organization of the system itself. The most common way to create categories is the so called aggregation. Through this process it is possible to classify distinct elements into categories suppressing the differences among the elements pertaining to the same category but focusing on the differences among the categories themselves. In biology this is the case of different organisms that are grouped in a population or populations into species. This way of proceeding makes it possible to create functional groups that can be seen as a category for the functioning of a particular system. These functional groups, which can be viewed as an aggregation of individual agents, Holland calls *meta-agents*. Meta-agents can be used for a simplified representation of the hierarchical organization of a particular system. Following this rational we can, for instance, represent the human body as a system organized hierarchically by meta-agents represented by the organs, which in turn are made by mega-agents such as cells. The same rational can be applied to social systems. A state can be viewed for instance as a system organized hierarchically by meta-agents represented by the regions, provinces, communities and finally households. In this representation each meta-agent represents an aggregation of the characteristics of the lower hierarchical levels. The same concepts can be expressed using the term *holons*. According to Allen and Starr and more in general terms to hierarchy theory[1] (Gibson et al., 1999; Salthe, 1985; Koestler, 1967; Pattee, 1973), holons are entities that are at the same time parts of a greater whole and a whole made up of smaller parts (Allen and Starr, 1982). Holons therefore are characterized by a double nature: they are organized internally in nested hierarchies[2] and simultaneously they constitute elements of a greater hierarchy (Pastore et al., 1999). Holons therefore are elements of nested hierarchies affected by an inherent "indeterminacy" because of their innate duality. When dealing with these entities it is possible to describe them in terms of a structure and in terms of function. In the former case, one can see how lower-level processes guarantee a function that can be detected as an emergent property only at the larger scale. In the latter case, one can analyze the meaning of the activities performed by the holon within its context; at this larger scale, one necessarily lose track of details (Giampietro and Pastore, 1999). In practical terms, one can analyze holons only referring to both structure and function at the same time. These characteristics of CAS explain the need of using parallel, alternative descriptions.

In other words, holons, entities and meta-agents are different ways to explain the same general characteristic of complex adaptive systems, which is their hierarchical internal organization. This characteristic makes necessary the simultaneous consideration of different space-time scales when trying to analyze CAS. The following figure shows a multi-scale representation of a general complex adaptive system, in which three levels are represented.

[1] The Hierarchy theory is a dialect of general systems theory. It has emerged as part of a movement toward a general science of complexity. Hierarchy theory focuses upon levels of organization and issues of scale. There is significant emphasis upon the observer in the system. Hierarchies occur in social systems as well as in biological structures (Allen and Starr, 1982).

[2] Nested hierarchies involve levels which consist of, and contain, lower levels.

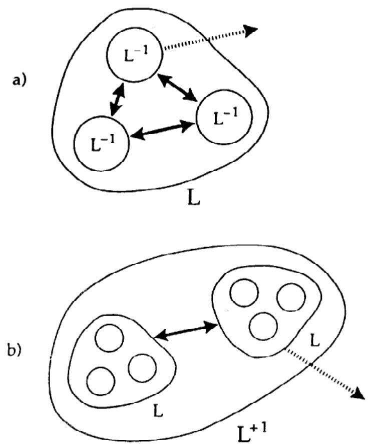

Figure 1 Graphical representation of hierarchical entities based on hierarchy theory. Level L represents the system of interest for the purpose of the analysis, while L^{+1} and L^{-1} the lower and upper levels embedding the system itself. *Source*: Allen and Hoekstra (1992).

Following Salthe, in hierarchical systems higher levels control (regulate, interpret, harness) lower levels. So, higher levels provide boundary conditions on the behaviors of lower levels, behaviors initiated by still lower level configurations (Salthe, 1985).
Moreover, one of the basic elements that characterize CAS is “adaptation”. According to Holland adaptation is the sine qua non of CAS (Holland, 1995). Adaptation in biological term is the process whereby an organism fits itself to its environment. Different systems have different adaptation times as it has been illustrated in the following figure.

SYSTEM	MODIFICATION TIME
central nervous system	seconds to hours
immune system	hours to days
business firm	months to years
species	days to centuries
ecosystem	years to millennia

Figure 2 Adaptation and learning. Source: Holland, 1995

Heterogeneity and hierarchical organization of rural systems

Based on the above considerations, rural systems are here analyzed as a combination of different components that make up their heterogeneity and their hierarchical organization. Rural systems can be viewed for instance at the same time as a combination of individuals and/or of different land uses. These two components are characterized by the presence of nonlinear interactions (individuals depend on agriculture for the satisfaction of their basic needs and at the same time they influence with their decisions the land use of a particular area). Through these interactions rural systems become organized hierarchically into structural entities. This means that a group of individuals is organized for instance in a bigger entity which could be the household, households make up a bigger entity which could be a village, villages an island and so on. The same example can be expressed by the use of different land uses and their aggregation. Following this rationale, it becomes possible to analyze rural systems, characterized by a vast amount of data, through the use of categories or meta-agents, trying to represent the intrinsic hierarchical organization of the system itself. Meta-agents can be defined as an aggregation of components making up a particular entity characterized by essential features. So, for instance, a household can be viewed as a meta-agent composed by an aggregation of individuals and characterized by essential features such as the time dedicated to different activities, the energy and food consumed, the income generated, and the profile of land use (this way to characterize rural systems has been used in the Chinese case study). This way to proceed makes it possible to analyze rural systems based on the representation of different hierarchical levels, in which each level is a meta-agent which in turn is composed by an aggregation of meta-agents at the lower levels. Starting from the lower level of analysis is then possible through a process of aggregation to estimate the information that characterizes the higher levels embedding the lower level itself. According to Holland, aggregation enters into the study of CAS in two different ways. The first refers to a standard way of simplifying complex systems. Modelers aggregate similar things into categories and then treat them as equivalent. Aggregation in this sense is one of the chief techniques for constructing models. Researchers decide which details are irrelevant for the questions of interest and proceed to ignore them. In such a way, the category becomes a building block of the model. The modeler must decide which features to make salient (exaggerate), and which features to eliminate (avoid), in order to answer the questions. Different selections emphasize different aspects of the CAS under investigation, yielding different models. The second sense of aggregation is closely related to the first, but it is more a matter of what CAS do, rather than how we model them. It concerns the emergence of complex large-scale behaviors from the aggregate interactions of less complex agents. Aggregates so formed can in turn act as agents at a higher level – meta-agents. The interactions of these meta-agents are often best described in terms of their aggregate properties. Thus, we speak of the gross domestic product of an economy, or the identity provided by the immune system, or the behavior of a nervous system. Meta-agents can, of course, aggregate in turn to yield meta-meta agents. When this process is repeated several times, we get the hierarchical organization so typical of CAS (see figure 1).

Having in mind the concepts expressed above, in this thesis rural systems are analyzed trying to represent as much as possible their hierarchical structure as well as their interactions with external socioeconomic and environmental systems. This is done by the use of integrated approaches based upon the combination of multi-scale and multidimensional methodologies.

1.2 Introducing integrated analyses of sustainability: descriptive versus normative models

An integrated analysis can be defined as an approach that facilitates the integration of the social, economic and environmental dimensions in the study of the elements that characterize human-environment interactions, identifies and prioritizes key interactions among them, and determines policies and projects that have, as the final objective, the achievement of a sustainable management of coupled social-ecological systems. Integrated analyses of sustainability have been extensively used for the representation of the complexity that characterizes human systems as well as the interaction between human and natural systems. The practical implementation of the integrated approach principles requires the identification of specific economic, social and environmental factors, which are relevant at different levels of aggregation, so that the complexity of the systems under investigation is represented. To join economics and ecology together in such a sustainability assessment represents one of the main objectives of nowadays integrated researches. Integrated analysis can also be seen as part of the challenging effort that is required for analysing the sustainability of human societies representing as much as possible their multidimensional characteristics and complexity (Ostrom, 2009; Holland, 1995; Levin, 1999).

Different types of models can be used for the realization of an integrated analysis of coupled social-ecological systems, which can be also applied in the analysis of sustainability. According to a simplified categorization, it is possible to distinguish between descriptive and normative models. Descriptive models aim primarily at gathering knowledge (i.e. descriptions and explanations) about the object of study but do not wish to modify the object. The target is to find out how things are, or how they have been. The approach may also include gathering opinions about the desirability of the present state of things, but it does not include planning any improvements. On the other hand, normative models are perspective models which evaluate alternative solutions to answer a particular research question. In normative study models are used for describing the existing problems and defining the improvements to the object of study. Therefore, normative models deal with questions of what sort of policies ought to be pursued, in order to achieve desired outcomes.

Normally a descriptive study proceeds through successive stages, such as: (1) to demarcate the object and population under investigation; (2) to select a sample; (3) to gather the empirical data and analyze them; and finally (3) to assess the findings. On the other hand, a normative model is optimally implemented through the realization of stages, such as: (1) investigation of the initial state and defining the objectives of the study; (2) analysis of relationships and possibility to change things; (3) synthesis of the previous analyses and creation of alternative options; (4) evaluation of the alternative options.

Therefore, in normative study models are mainly used for describing the existing problems and analyzing alternative options to the object of study. Descriptive model can also be transformed into a normative model by adding an evaluative dimension to it.

Two examples of normative models used in the analysis of sustainability are: Cost-Benefit Analysis (CBA) and Multi-Criteria Decision Analysis (MCDA). While, some examples of descriptive models are: Social Metabolism Analyses (SMA), which in turn can be distinguished in Multi-scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) and Material and Energy Flow Analysis (MEFA).

The concept of social or industrial metabolism (Fischer-Kowalski, 1998; Fischer-Kowalski and Hüttler, 1998; Ayres and Simonis, 1994) captures biophysical aspects of the economy and allows investigating interactions between societies and their natural environment. It has proven useful to study sustainability problems related to the use of natural resources (emerging both on the input and the output side) and social metabolism has been established as a key concept in sustainability science. This way to analyse social systems fully reflects the concept of Bioeconomics suggested by Georgescu-Roegen (Georgescu-Roegen, 1971, 1975; Mayumi and Gowdy, 1999), as well as by the pioneering work done in the energy analysis of economic fluxes by various researchers in the past three decades (Leach, 1976; Pimentel and Pimentel, 1979; Martinez Alier and Schlupmann, 1987).

According to these studies, analysing the metabolism of human systems means integrating the economic flows with matter and energy flows within scientific analyses.

In that sense, social metabolism approaches constitute a way toward the analysis of coupled social-ecological systems comprising simultaneously socio-economic and environmental factors (Giampietro and Mayumi, 2000a, 2000b). This approach is particularly useful to investigate whether or not a human system is following a sustainable path over time or in comparison with other systems (see for example Falconi, 2001; Ramos et al., 2009; Kuskova et al., 2008).

Cost-benefit and multi-criteria analyses are both utilized to evaluate various alternative projects or objects to define the best one according to a set of evaluation criteria (in the analysis of sustainability usually the criteria are selected trying to represent the economic, environmental and social dimensions). Cost-benefit analysis (CBA) is a single valued approach which seeks to assign monetary values to the criteria (indicators which represent the costs and benefits associated with the project analyzed). All significant impacts and externalities need to be valued as economic benefits and costs. However, since many environmental and social effects may not be easy to value in monetary terms, CBA is useful mainly as a tool to assess economic and financial outcomes. However, it has been extensively applied in the analysis of the sustainability of alternative options, whose realization involved environmental and social externalities. Multi-criteria analysis is particularly useful when a single criterion approach like CBA is not adequate because significant environmental and social impacts need to be included in the analysis and monetary values cannot be assigned. In MCA, the alternative options to be evaluated are specified and corresponding evaluation criteria and indicators are identified. Unlike in CBA, the indicators does not have to be evaluated in monetary terms, instead different environmental and social measures may be used. Thus, more explicit recognition is given to the fact that a variety of both monetary and non-monetary objectives and indicators may influence policy decisions. MCA provides techniques for comparing and ranking different outcomes, even though a variety of indicators are used. Both models are usually applied for the creation and evaluation of different scenarios of development or alternative projects. Based on the above considerations, employing normative approaches, such as multi-criteria analysis, is essential to capture the multidimensional aspects of the policies' objectives. Multi-criteria approaches are in fact able to include in the analysis specific evaluation criteria, by the realization of quantitative and qualitative assessments using factors in the environmental, social and economic dimensions (Janssen and Munda, 2001;

Munda, 2008). Various examples of empirical studies have applied multi-criteria approaches in the field of public policy and environmental management (see as an example Gamboa, 2006; Gamboa and Munda, 2007; Munda, 2006; Russi 2008; Stagl, 2006). These studies have been able to deal with the multidimensional characteristic of sustainability integrating different perspectives, aspects and dimensions.

The descriptive and normative models described above are all used in the field of integrated analysis of sustainability issue. They aim at integrating socio-economic together with environmental analyses by the use of multidimensional indicators explaining the performance of a particular system. However, the way to do that differs from a model to another. Therefore, their application in the analysis of sustainability depends on the issue to be analysed and the aim to be achieved.

In the next sections I present how integrated analyses of sustainability, and in particular some specific descriptive and normative models, can be applied to analyze two important aspects of sustainability related to rural systems and rural development policies:

1) The sustainability of different patterns of agricultural systems, based on a comparative analysis according to the selection of multidimensional criteria;
2) The effectiveness of rural development polices to achieve sustainability goals in rural areas, according to the multidimensional representation of the rural policies' objectives.

This is done by the use of a particular multi-criteria approach, called Social Multi-criteria Evaluation (SMCE), and of a social metabolism analysis based on Multi-scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) approach. The two approaches are explained in details in the next chapter.

2. MULTI-SCALE AND MULTI-CRITERIA APPROACHES TO ANALYZE RURAL DEVELOPMENT POLICY'S SUSTAINABILITY

Summary

This chapter provides a general definition of rural development policy and the relation between rural development policies and sustainability. It also explains the main aspects and goals that characterize RDP in various countries, in particular in Italy and China including also some considerations about the European rural development policy.

After that, the chapter provides a description of the main methodologies used in this thesis for the integrated analysis of RDP.

In particular, the main aspects and concepts that characterize Social Multi-criteria Evaluation (SMCE) and Multi-scale Integrated analysis of Societal and Ecosystem Metabolism (MuSIASEM) are presented.

Finally, it explains the reasons why, in the light of the main aspects of RDP at different levels, I decided to apply an integrated approach based on the above mentioned methodologies to assess RDP's sustainability in two selected rural areas of Italy and China.

2.1 Rural development policies and sustainability

Rural development in general is used to denote the actions and initiatives taken to improve the standard of living in non-urban areas (the countryside, and remote villages). These areas are usually characterized by income per capita and population density lower than urban areas[3]. According to the World Bank the 75% of the world's poor[4] live in rural areas, even though in fast urbanizing countries (such as China and India) poverty is increasingly becoming a predominantly urban phenomenon.

In the last years, rural population has showed a decrease of 13%, ranging from the 64% of the total world population in the 70's to 51% in 2005 (United Nation population division) (figure 3).

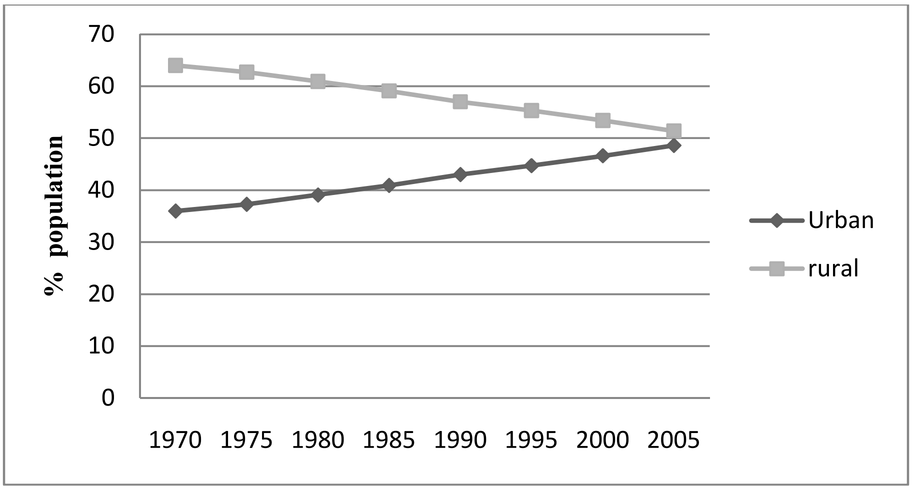

Figure 3 Changes in world rural-urban population from 1970 to 2005 (% values). Source: United Nation population division (retrieved from http://esa.un.org/unup/)

The process of urbanization of rural population represents an increasing phenomenon in all over the world. According to the World Bank projections, related to the population growth rate of both rural and urban areas from 1960 and predicting total for 2025, the level of people living in cities is constantly increasing. Moreover, according to the latest UN estimates, almost all of the world's population growth between 2000 and 2030 will be concentrated in urban areas in developing countries. By 2030, almost 60% of the people in developing countries will live in cities (FAO, 2003). If present trends continue, urban population will equal rural population by around 2017 (figure 4).

[3] Based on Wikipedia definition available at http://en.wikipedia.org/wiki/Rural_development .
[4] Poor people are considered those living on less than USD 1 per day.

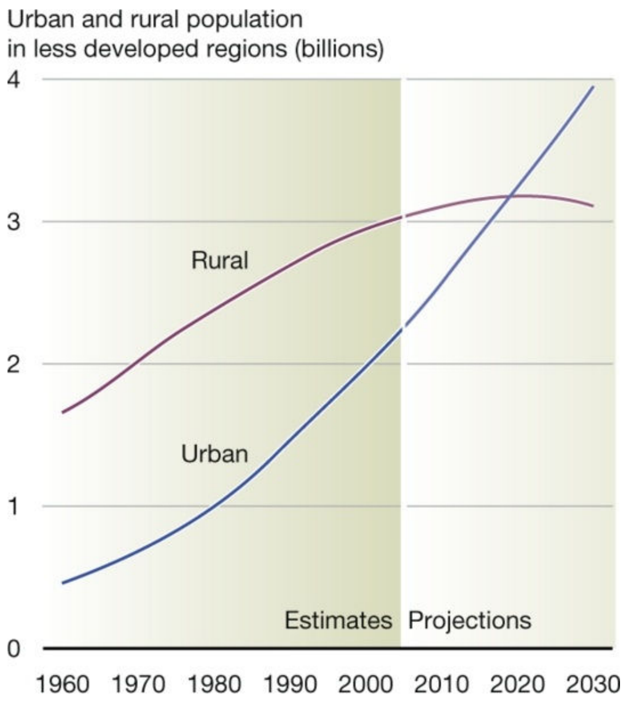

Figure 4 Urbanization in developing countries between 1960 and 2030. (2009).
In *UNEP/GRID-Arendal Maps and Graphics Library*. (Retrieved, July 1, 2009 from http://maps.grida.no/go/graphic/urbanization-in-developing-countries-between-1960-and-2030)

Urbanization is mostly determined by the rural-urban gaps in income, poverty and living standards. However, poverty is now growing faster in urban than in rural areas. One billion people in less developed regions[5] live in urban slums, which are typically overcrowded, polluted and dangerous, and lack basic services such as clean water and sanitation (UNFPA, the United Nations Population Fund).

Rural development actions mostly aim at the social and economic development and environmental protection of rural areas to reduce the above mentioned rural-urban gaps, to avoid the massive migration of rural people to the cities and concurrently to protect natural resources.

People living in rural areas are in fact heavily reliant on natural resources for their livelihoods: soil, water, forests and fisheries underpin commercial and subsistence activities and often provide a safety net to rural people in times of crises. These natural resources which are abundant in many developing countries represent an important asset and potential wealth for rural people and their communities. As many of these natural resources are renewable and if properly managed this wealth is long term. Improved

[5] Less developed regions: they comprise all regions of Africa, Asia (excluding Japan), Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia.

natural resource management can support long-term economic growth, from which people, in rural areas and elsewhere, can benefit to achieve and sustain social progress and development.

The definition of the strategies and programs for the achievement of the rural development goals are usually top-down from the local or regional authorities, regional development agencies, NGOs, national governments or international development organizations. On the contrary, interventions are usually designed at the very local scale, such as river basin, farming system, village or household.

Currently, the majority of the rural development policies around the world (from developed to developing countries) aims at the implementation of a sustainable development in rural areas. As a consequence, they entail the implementation of interventions able to achieve different goals afferent to different dimensions and scales. In other words, rural development interventions should be able to guarantee at the same time the improvement of the economic, environmental and social conditions of the rural population and the rural ecosystem at different scales, such as farming system, household, village, region up to the national level.

So, at the global level, while urban poverty is growing fast and matters enormously, rural development means first a transformation of rural lives and livelihoods. Such a strategy would also have a positive impact on forced out-migration, which is often direct consequence of lack of rural opportunities (IFAD, 2005).

A lot of rural development strategies all over the world seek to build local support for local processes. In most rural areas local bottom-up processes and local institutions managed by or accountable to the rural people are essential for the achievement of sustainable results.

Summarizing, rural development policies have to guarantee a sustainable development of rural areas at the local level based on the achievement of the following main goals:

- Improving the social condition of rural people;
- Protecting the natural resources in rural areas;
- Reducing the forced out-migration creating rural opportunities;
- Improving the economic performance of rural people.

Therefore, according to policy priorities interventions should be able to guarantee the achievement of the above mentioned objectives across scales (individual, household, farming system, village) seeking for a *compromise solution* between different dimensions (social, environmental and economic).

The problem, that often arises when policy-makers try to design sustainable interventions in rural areas, is the difficulty to deal simultaneously with the multidimensional and multi-scale characteristics of development goals. The analysis of sustainability in rural areas usually refers only to one dimension and/or one scale. As a consequence, often rural interventions turn out unsuccessful in terms of the achievement of a sustainable development.

In this context, Social Multicriteria Evaluation (SMCE) (Munda, 2004) and multi-scale (Giampietro, 2003) approaches can be helpful in structuring decisions and analysis on RDP because they enable taking into account at the same time the various impacts in different dimensions and scales.

Based on the above considerations, the present thesis examines by means of SMCE and multi-scale approaches, the effectiveness of RDP in achieving sustainability in two selected rural areas. They refer respectively to a rural area located in central Italy, and one located in eastern China. In the first case study, the effectiveness of the common agricultural policy (CAP) in achieving sustainability, in the presence of soil degradation, is analyzed based on the comparison of different agricultural practices by means of economic, environmental and social indicators at the farm level. In the case of China, the effectiveness of local rural development interventions in achieving sustainability is analyzed at the household and village levels. The first case is mostly related to agriculture and the environmental protection of agricultural areas. Alternatively, the second one refers mostly to the analysis of the environmental, social and economic impacts of urbanization strategy.

Before going into the details of the case studies, the next sections briefly describe the main characteristics of RDP in Italy and China and the main aspects that characterize SMCE and Multi-scale methodologies.

2.1.1 Rural development policy in Europe/Italy

Italy as one of the member states of the European Union follows the EU guidelines for the design and implementation of rural development in its territory.

The EU has in fact a common rural development policy, which nonetheless places considerable control in the hands of individual Member States and regions.

In this context, every Member States, and therefore Italy, must set out a rural development program, as well as the policy measures, referring to the essential rules and guidelines as indicated in the Council Regulation (EC) No. 1698/2005. Under this regulation, rural development policy has to be designed by each Member States taking into account the following three main themes or “thematic axes” of the EU:

- improving the competitiveness of the agricultural and forestry sector;
- improving the environment and the countryside;
- improving the quality of life in rural areas and encouraging diversification of the rural economy.

The above mentioned points relates to the principles and guidelines defined by the Lisbon Strategy for jobs and growth and the Göteborg Strategy for sustainable development. According to the above mentioned strategies, each Member State has to provide supports to rural areas as well as cities and towns in the EU with the aim to provide people with a better standard of living in an environmentally and socially sustainable way. The agricultural sector of the EU regulated by the Common Agricultural Policy (CAP) plays a crucial task in the achievement of sustainability in rural areas.

The guiding principles for the contribution of the Common Agricultural Policy (CAP) to the Lisbon Strategy have been confirmed in Göteborg in 2001 and in the Lisbon Strategy conclusions in June 2003: "Strong economic performance" that goes hand in hand with "the sustainable use of natural resources".

According to the Council Decision (2006/144/EC) on community strategic guidelines for rural development, “agriculture continues to be the largest user of rural land, as well as a key determinant of the quality of the countryside and the environment”. The importance of agriculture in the rural areas of EU is related to the multifunctional role farming plays in the richness and diversity of landscapes, food products and cultural and natural heritage.

According again to the Göteborg Strategy, to protect the multifunctional role of agriculture and farming, the CAP should contribute to achieving sustainable development encouraging healthy, high-quality products, environmentally sustainable production methods, including organic production, renewable raw materials and the protection of biodiversity. Sustainable agriculture and organic production is then recognized by EU regulation as one of the crucial interventions for the achievement of a sustainable management of rural areas. According to the Council Decision (2006/144/EC) on community strategic guidelines for rural development "in Europe, much of the valued rural environment is the product of agriculture. Sustainable land management practices can help reduce risks linked to abandonment, desertification and forest fires, particularly in less-favoured areas. Appropriate farming systems help to preserve landscapes and habitats ranging from wetlands to dry meadows and mountain pastures. In many areas, this is an important part of the cultural and natural heritage".

Rural areas in EU therefore face particular challenges as regards growth, jobs and sustainability. According to the EU regulations, rural development policy in each member states in general and therefore in Italy must help rural areas to meet the general objective of sustainability.

2.1.2 Rural development policy in China

Before going into the details of the current rural development policy of China, this section provides a brief introduction related to the main aspects and reforms that have characterized the organization and management of Chinese rural areas from mid 1900's to our days. This information is fundamental to understanding both the current situation of China's rural areas and the State's rural development policy objectives for the future modernization of the Chinese countryside.

China's rural reform

Until 1949 land tenure in rural areas of China has been based on collective ownerships. Immediately after China's 1949 revolution, a very important land reform changed the land tenure in china giving land ownership to the tenant farmers (Xiwen, 2009).

Beginning in the mid-1950s, however, Mao introduced collective farming, moving ultimately to compulsory and very large collective farming units—the giant communes of the Great Leap Forward. After that much smaller collective units, based on the residential rural community or "production team" were introduced, and remained the norm until the late 1970s. In a process that began in 1978 and was completed by 1984, China then became the first collectivized agriculture to break up its collectives and return to individual farming, under the "Household Responsibility System" (HRS) (FAO, 1999).

After that a 30-year Right Policy was introduced in 1993. This policy gave to the farmers the right (but not a legal requirement) to use and manage their land for 30 years. Then, in

1998 a Land Management Law (LML) was introduced. This law permitted to legalize such rights in formal written contracts. In 2003 the LML low was reinforced by a new law, Rural Land Contract Law (RLCL), which gave to the farmers an additional assurance of 30-year rights on the land regularizing the contracts and incorporating in formal law the protection of 30-year farmers' tenure. According to the rules of the law, the term of the contract of land use on a household basis in rural areas should be "at least" 30 years.

China's modern rural development policy

The rural reforms described above have changed the economic and social structure of the countryside of China and therefore the main strategies and objectives of Chinese rural development policy. The rural development strategies of China were formulated for the first time in 2001, with the 10th Five-Year Plan. The Plan identified as a national goal the achievement of a "*xiaokang*" (all around better off) society. This concept is not only related to the economic development of rural areas but comprises also the environmental and social sustainability and the application of modern science and technology to raise productivity and generate greater benefits. The key strategies of the 10th Five-Year Plan are as follows:

- Increasing flexibility of resource movements;
- Emphasizing on human resource development;
- Reducing social disparities, especially rural-urban and regional gaps;
- Improving the management of the rural-urban transition;
- Protecting the environment and natural resources.

The Government stressed also as a strategic priority poverty reduction and sustainable development in rural areas.

As concerns, in particular, the cities and rural areas disparities, the Government emphasizes that an effective reduction in the urban-rural income gap should be based on the transformation from rural to urban and from agriculture to industry and services. At the same time it also recognizes that successful development has to consider the preservation of the rural economy. Therefore, farmers' income and overall well being have been at the core of the discussion.

After China's 10th Five-Year Plan related to development strategies, to be achieved between 2001 and 2005 a new Plan, the 11th Five-Year Plan was designed for the period 2006-2010. The new plan embraces the main strategies of the previous one and recognizes as a strategic guidance the concept of building a "new socialist countryside". This strategy will be achieved through the improvement of infrastructure, health and education, social development, the quality of the environment.

2.1.3 Europe and China, different but complementary development strategies

Based on the analysis of rural development policies, at the global, European and country levels (Italy and China), presented until now, one can easily recognize that all of them entail the achievement of a sustainable rural development. However, the specific strategies and interventions designed to achieve it differ between geographical regions, political and economic conditions.

On one side, Italy and Europe fully embrace the guidelines designed at the global level based on the protection of the countryside through a diversification of the rural economy to avoid the out-migration (i.e. the abandonment of rural areas). In this direction, a special attention is given to the negative consequences in terms of environmental degradation of rural areas as a consequence of the abandonment of agricultural activities and, at the same time, to the importance of the realization of conservative agricultural practices.

On the contrary, China supports the rural-urban migration as a strategy to reduce the economic rural-urban gap.

Based on these two different aspects characterizing RDP (Europe versus China strategies), this thesis analyzes, on one side the effectiveness of European RDP (i.e. Common Agricultural Policy – CAP) to reduce rural areas abandonment and to support conservative agricultural practices. On the other side, it explores the economic environmental and social consequences at the local level, i.e. household and village, of the implementation of urbanization strategies designed for the development of a selected rural area of China.

Before going into the details of the two case studies analyzed, next sections provide some basic information related to the methodologies used for the integrated analysis of RDP's sustainability, together with an explanation of the reasons why they have been chosen.

2.2 Multiple- Criteria Decision Analysis (MCDA) and Social Multi-criteria Evaluation (SMCE)

2.2.1 The Multiple-Criteria Decision Analysis (MCDA): an introduction

The Multiple-Criteria Decision Analysis (MCDA) is a method aimed at supporting decisions based on a comparison of alternative options in order to obtain an order of preference of possible plans of action (ranking of the alternatives). The comparison is made on the basis of a set of evaluation criteria[6] that can be evaluated both qualitatively and quantitatively and usually represent different dimensions of analyis (e.g. social, economic and environmental).

In other words, the aim of a MCDA is to decide between a set of alternatives the option that best represents a compromise solution taking into account all the evaluation criteria, given that it is almost impossible to satisfy all the criteria at the same time. According to Munda "the major strength of multi-criteria methods is their ability to resolve questions characterized by various conflicting evaluations, thus allowing for an integrated assessment of the problem at hand" (Munda, 2008).

A typical multicriteria problem, with a discrete number of alternatives, can be described as follows (Munda, 1993): A is a finite set of alternatives and m is the number of the evaluation criteria gi with i= 1,2,.. m considered relevant in a decision problem. In such a context the alternative a Є A is considered to be better compared with the b alternative if gi (a) > gi (b). In such a way it is possible to structure the decision problem inside a tabular matrix (see table 1) in which, given a set A of alternatives and a set G of criteria (with m alternatives and n criteria) it is possible to build a matrix P n x m called an impact or evaluation matrix, in which the typical element pij (i= 1,2…, m; j = 1,2..., n) represents the evaluation of the j-th alternative on the basis of the i-th criterion.

Table 1 Example of an impact or evaluation matrix

Alternatives / Criteria	a_1	a_2	…	a_n
g_1	$g_1 (a_1)$	$g_1 (a_2)$	.	$g_1 (a_n)$
g_2	.	.	.	.
….	.	.	.	.
g_m	$g_m (a_1)$	$g_m (a_2)$	.	$g_m (a_n)$

Source: Munda, 1993

[6] The evaluation criterion represents the function that associates each alternative with a variable that indicates its desirability according to expected consequences related to the same objective (Munda, 2008).

Therefore, the information contained inside an impact matrix is the following:

- intensity of the preferences (when there are quantitative values);
- number of criteria supporting an alternative;
- weights attributed to each single criterion;
- relation of each single alternative to all the others.

The combination of the above mentioned information can be achieved using a range of different techniques for aggregation of the evaluation criteria, in order to obtain the final result (ranking of the alternatives). Such aggregation techniques usually differ with respect to both the choice of the type of weights (trade-offs or coefficient of importance) and the capacity to evaluate different types of information, i.e. qualitative and/or quantitative.

As concerns the weights, the choice between the utilization of weights as trade-offs or coefficient of importance has a huge impact on the final evaluation of the alternatives in terms of criteria compensation. Weights as trade-offs with intensity of the preferences (cardinal values, quantitative information) generate multi-criteria compensation method, which is the possibility that a very bad performance of an alternative in relation to a particular criterion is compensated by an excellent performance with respect to another criterion.

This aspect is particularly significant when multi-criteria analysis is applied to public policies. In this case in fact the evaluation criteria usually refer to different dimensions of analysis (e.g. economic, environmental and social) and most important, all of them are equally significant from a policy maker point of view[7]. In this case, the use of weights as trade-offs doesn't seem the best choice. Alternatively, if one considers for example the private sector the economic dimension is usually considered more important than the environmental one. In this case, a MCDA that utilizes weights as trade-offs could be preferred. In both cases, the final ranking of the alternative options doesn't represent a solution maximising all the criteria at the same time, but it always refers to a *compromise solution*. In other words, the best alternative resulting from the multi-criteria decision analysis doesn't correspond to the best solution according to all the evaluation criteria simultaneously but it represents the best *compromise solution* in relation to the criteria chosen for the case analysed.

Summarizing, the steps that characterise the realization of a typical MCDA are as follows:

- identification of the policy options;

[7] We will see in the second part of this thesis, the importance of the compensatory aspect of MCDA in the analysis of sustainability in agriculture based on the use of economic, environmental and social criteria evaluated both quantitatively and qualitatively.

- identification of the evaluation criteria;
- attribution of criteria scores;
- application of an aggregation procedure;
- analysis of the results.

The main advantage of making a multi-criteria analysis is its capacity of taking into account various criteria evaluated quantitatively with different units of measurement together with qualitative, fuzzy and stochastic evaluations. At the same time MCDA gives to the decision maker the opportunity to select different evaluation procedures (compensatory, partially compensatory or non compensatory methods) according to the case analysed and the objectives to be achieved. For such reasons it is especially suitable for management choices in the environmental field and in the public policy field where there are usually various and equally important dimensions to consider (economic, social, ecological).

2.2.2 Social Multi-Criteria Evaluation (SMCE)

A Social Multi-criteria Evaluation (SMCE) can be defined as a type of MCDA that entails the inclusion of stakeholders in the process of defining the alternative options and of choosing the evaluation criteria for the identification of the best compromise solution.

It deals with the necessity to build a process of decision making in the public sector as much as possible transparent. In this context, *transparency* means the ability to recognize the different groups of interest that play a particular role in the problem under investigation, together with their interests and expectations.

In this context, the foundations of the SMCE can be found in the concepts related to complex system theory and "Post Normal Science". According to complex system theory natural systems as well as social systems are characterized by deep complexity (Holland, 1995; Levin, 2000; Rosen, 1987; Allen and Starr, 1982). Deep complexity means the presence of various dimensions (economic, environmental and social) and scales of analysis when one tries to represent and examine complex systems.

As a consequence, policy decisions, which more and more need to refer to the analysis of the coupled social-ecological systems, have also to deal with such a complexity, trying to represent as much as possible the various dimensions and levels of the investigation problem to be handle.

At the same time, according to Post-normal Science (PNS) (Funtowicz and Ravetz, 2003), policy problems and the related decisions have increasingly to deal with uncertainty and a plurality of legitimate perspectives that the normal scientific community doesn't take into account because of a lack of appropriate tools of analysis (this is for example the case of cost-benefit analysis- CBA, in which the analysis of the social consequences of a project is often avoided because of the difficulty to evaluate them in monetary terms). This can apply for example to modern problems such as the case of taking decisions related to different climate change scenarios or the introduction of GMOs in agricultural production. In both cases uncertainties about the consequences on the economic, environmental and social points of view are so high that there is the need to integrate the traditional information used by scientists with the involvement in the process of decision making of all the stakeholders, including local people. Local people can contribute with information and ideas that are not at the disposal of the experts.

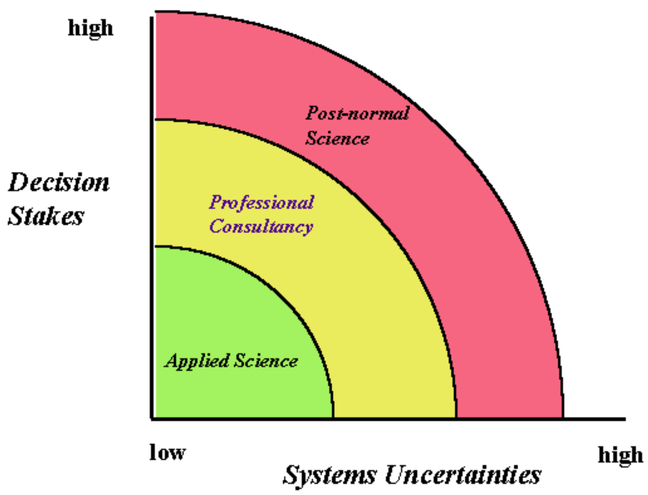

Figure 5 PNS diagram. (*Source*: Funtowicz and Ravetz, 2008)

Figure 5 shows where the PNS can be located in relation to a traditional problem-solving. The figure illustrates that when system uncertainties and decision stakes are low, applied science can provide a good support for decision making. Alternatively, when uncertainties increase there is the need to use other kind of information such as the ones provided by professional consultancy and social actors.

In this context, the SMCE represents a tool able to take into account different dimensions of analysis (feature that is characteristic of a MCDA) and at the same time to include in the process of decision making a plurality of legitimate perspectives. The latter is achieved

by the realization of institutional and participatory approaches. Moreover, the SMCE is based on the simultaneous use of quantitative and qualitative values. This feature is essential for the inclusion of the social consequences and impacts related to the realization of a particular project or policy intervention, which often cannot be evaluated in quantitative terms. At the same time, SMCE allows for the use of different unit of measurements avoiding the conversion to only one established value, such as for example the use of monetary values. This feature makes it possible to increase the possibility of including different aspects of a problem, such as the social dimension, that otherwise, as often happens, are difficult or even impossible to incorporate in the final evaluation.
The basic steps that characterize the realization of a SMCE are as follows (Munda, 2004):

1) Definition of the problem;
2) Institutional analysis;
3) Generation of the policy options;
4) Construction of the multi-criteria impact matrix;
5) Application of a mathematical procedure;
6) Sensitivity analysis.

Definition of the problem

The first step that characterizes the realization of a SMCE is the definition of the problem that needs to be investigated. That is, in other words, the definition of the questions proposed for solution or discussion. Sometimes, a single problem can be associated with various questions to be addressed related to various different perspectives and perceptions. For these reasons, the definition of the problem to be investigated in a SMCE frequently corresponds to a learning process that includes as much as possible all the social actors' points of view.

Institutional analysis

Institutional analysis is part of the social sciences and it is typically used for the study of how rules shape human behavior (Gibson and Koontz, 1998; Ostrom, 1999) and concurrently to explore the interests, expectations, perceptions and the role of the various social actors involved in a particular problem structuring and decision making process (Dente et al., 1998; Ingram et al., 1984; De Marchi et al., 2000). Researchers using an institutional approach focus on how individuals and groups interact, how institutions operate, and how social actors construct their positions in relation to a specific issue.

In an SMCE the institutional analysis is mainly used for the identification of the social actors' expectations and interests and to shed light on the interaction patterns among them. The latter refers to the analysis of how different interest groups position themselves in relation to other groups involved in the same decision making process. The identification of the social actors is based on the analysis of information related to the political and legal framework, the analysis of the historical evolution of the subject under investigation using various sources of information such as local press, official documents, books, articles and the information available. The above mentioned information is in a second step integrated with individual interviews to key agents, or interest groups or causal samples and focus groups (i.e. the participatory process).

Generation of the policy options

One of the special characteristics of the SMCE is related not just to the inclusion of the social analyses in the process of structuring and defining the subject under investigation, but also to the contemplation of the social actors' interests and expectations in the definition of the policy options. In this sense, the SMCE is meant to take into account, as far as possible, a plurality of perceptions and needs related to the issue under investigation in the generation of the policy alternatives, as well as in the elicitation of the evaluation criteria. In most of the cases in fact the inclusion of the stakeholders can allow the definition of new possible alternatives that otherwise the policy makers alone shouldn't have taken into account (Munda, 1994). However, the inclusion of the social actors in the process of generating the policy options and the evaluation criteria depend strongly on the problem under investigation. In some cases the policy options are defined by the analyst because for some reasons there is not the necessity or it is too difficult to include the social actors. This could be for example the case in which the SMCE is used for the evaluation of the impacts of alternative policy options already designed by local institutions. In the latter case, the social actors could be included in the evaluation process asking for their opinions related to the various policy interventions and eventually including them in the definition of the evaluation criteria and criteria scores, but not in the definition of the alternatives to be evaluated.

Construction of the multi-criteria impact matrix

The multi-criteria impact matrix represents the first result of the social multi-criteria evaluation process. It illustrates the simultaneous representation of the alternative options and the related criteria scores (see table 1). In other words, it shows the performance of the options in relation to the indicators chosen to evaluate them. Usually the evaluation criteria or indicators are related to different dimensions of analysis (ecological, economic, social, and technological). Differently from other methodologies used to evaluate policy options, such as the CBA, each criterion is evaluated in its own unit of measurement.
The impact matrix contains all the information necessary for the final evaluation of the alternatives based on the application of the aggregation procedure and the resulting construction of the final ranking. Looking at the impact matrix it is in fact already possible to recognize which alternative performs better than the others in relation to a particular criterion. Even though by the application of the aggregation procedure it is then possible to assess which alternative reaches the best compromise solution in relation to all the evaluation criteria.

Application of a mathematical procedure

The application of a mathematical aggregation procedure is the MCDA step that makes it possible to obtain the final ranking of the alternatives. Many multi-criteria aggregation procedures have been developed since the 60's (for a review of the various model used in MCDA see Munda, 2005). These procedures, according to the information contained in the impact matrix, generate different aggregation conventions. For example the presence of intensity of preference (i.e. quantitative indicators) together with the use of weights as trade-offs generates compensatory multi-criteria analysis and gives the meaning of trade-offs to the weights (Munda, 2006). The latter means that a bad performance of an alternative option in relation to a criterion can be always compensated by a good performance in relation to another criterion. On the contrary, the use of weights as coefficients of importance (i.e. ordinal criterion scores) generates non-compensatory aggregation procedures.
According to Munda (2008), in the case of public policy evaluations or public choices related to sustainability, since the environmental, social and economic dimensions are considered of equally importance, it is preferable to use an aggregation procedure that avoids compensation. Following this rational, in the first case study I decided to use an

aggregation procedure that allows for choosing the degree of compensation that is applied among the various criteria (see the second part of the thesis, chapter 4, for a detailed explanation of the software and the aggregation procedure used to obtain the final ranking of the alternatives).

Sensitivity analysis

The last step of a SMCE is the sensitivity analysis. Sensitivity analysis is performed to investigate the robustness of a study when the study includes the application of quantitative models. It is used as a tool to ensure the quality of the modeling/assessment and to investigate to what degree the final conclusions are dependent to the choices made by the analyst during the evaluation procedure (Saltelli et al., 2008). In this thesis the sensitivity analysis has been used to test the robustness of the results obtained in relation to the first case study, and for adjusting the parameters defined by the operator (see chapter 4, for a detailed description of the procedure used to perform the sensitivity analysis).

2.3 Multiple-Scale Integrated Analysis of Societal and Ecosystem Metabolisms (MuSIASEM)

The Multiple-Scale Integrated Analysis of Societal and Ecosystem Metabolisms (MuSIASEM) has been introduced by Giampietro and Mayumi in 2000 (Giampietro and Mayumi, 2000a and 2000b) and subsequently formulated by Giampietro (2003). The MuSIASEM approach has been developed as a framework for the integrated assessment of sustainability issues across scales. According to the MuSIASEM approach social systems (i.e. a country, a village, a household, an individual) are viewed as complex adaptive systems (CAS)[8] operating on different hierarchical levels and across multiple scales and are viewed in different dimensions of analysis (economic, environmental and social).
The multi-scale and multidimensional aspects of social systems, makes it necessary the use of integrated assessments able to examine them by applying in parallel a "socio-economic reading" and a "biophysical reading" and considering also different scales of analysis.

[8] For a detailed explanation of the main characteristics of CAS and their definition see chapter 1.

The basic principles of the MuSIASEM approach can be found in the concept of "societal and ecosystem metabolism". According to Giampietro the "metabolism of human society" represents the processes of energy and material transformation in a society that are necessary for its continued existence (Giampietro et al., 2009). Based on these processes, the MuSIASEM approach establishes a representation of the performance of social systems by using a series of variables, referring to (1) the biophysical characteristics of the system, such as energy and land use, and (2) the socio-economic characteristics, such as human time and added value. The analysis of the relationships among economic information (represented by the added value), demographic information (represented by the human time) and biophysical information (represented by energy and land use) give us the possibility to have an integrated representation of social systems. At the same time, one of the most powerful characteristic of the MuSIASEM approach is the possibility of representing the multidimensional variables described above across scales. So that for example, the human time variable, expressed in hours of human activity, is not just related to the level of a country or a particular economic sector but it can be accounted for at the household, or even the individual level, scaling up to higher levels, such as economic sectors, the paid work as a whole or not paid work sectors, or the entire body of community activity, including sleep and rest. The same rationale can be applied to all the other variables, such as added value, energy or land use. The multi-scale representation of variables is based on the presence of relations of congruence between the elements pertaining to different levels, in the sense that the elements at the higher levels are obtained by an aggregation of the elements at the lower levels (for a detailed explanation of the MuSIASEM method used to represent variables across scales see chapter 3 of this thesis related to the China case study).

The multi-scale representation of variables is particularly useful for the identification of benchmarks for deeply understanding the system under investigation, based on (1) the comparison of values and indicators across scales, and (2) constraints coming from the interaction of the system with external contexts. For example, the labor productivity (LP), i.e. the added value produced per hour of human activity, of the agricultural sector of a particular rural area in China doesn't give us useful information about the level of the economic performance of the sector if we don't know the average LP of other economic sectors, of the entire region or of the main household types in the area. On balance, the representation of variables across scales gives us useful information to identify economic and environmental constraints (i.e. indicators are represented at different levels of analysis) for further development of a particular area of study and also for analyzing different scenarios.

Summarizing, the MuSIASEM approach is able to represent, in an integrated way, changes in the performance of an investigated system in relation to different criteria and on different scales. Therefore it provides the possibility to analyze sustainability of a particular area, of a project and of a policy intervention, based on:

- the analysis of trade-offs between different dimensions of analysis (economic, environmental and social);
- the analysis of economic and environmental constraints related to further development;
- the identification of a set of site-specific indicators;
- the analysis of constraints between dimensions.

2.4 Combining multi-criteria and multi-scale approaches for the analysis of RDP

Multi-criteria and multi-scale approaches are applied in this thesis for the analysis of rural development policies for two main reasons. The first one relates to the multidimensional aspect that characterizes the goals of RDP.

RDP interventions have in fact to guarantee at the same time:

- the economic development of rural areas, reducing the rural-urban gaps and increasing the income per capita of rural people;
- the conservation of natural resources and the protection of the environment;
- the improvement of the standard of living of rural people in terms of quality of life (more education, better sanitation and so on).

In this context, the multi-criteria approach provides a way of representing and analyzing the different goals of RDP, using economic, environmental and social criteria without reducing the analysis to just one or two of the above mentioned aspects.

The reason for using MuSIASEM relates to the fact that RDP goals while designed following a top-down approach have to be achieved by interventions usually implemented at the local scale but having consequences across scales. This is for example the case of CAP subsides designed at the farmer’s level for the realization of a particular agricultural practice or crop. The choice of the single farmer could also have consequences at the level of economic sectors, community, region, up to the national level. At the same time the choice of the Chinese RDP to "urbanize" a huge part of rural people to reduce the rural-urban gap has consequences not just at the level of households but also at the level of ecosystems, villages, towns and the whole country. In this context, the realization of a multi-scale analysis seems to be necessary to understand the impacts and consequences of RDP across scales.

Based on the above considerations, this thesis intends to show how multi-criteria and multi-scale approaches can be combined to provide a useful framework with which to structure an integrated analysis of RDP in order to assess their effectiveness in achieving sustainability across scales.

The next table shows a comparison of the two models based on their similarities and dissimilarities with respect to some particular features.

Table 2 Comparison between features of SMCE and MuSIASEM

Models / Features	SMCE	MuSIASEM
Multidimensional analysis	•	•
Participatory analysis for parameter setting and categories identification		•
Participatory analysis for scenarios' identification and evaluation	•	
Normative analysis	•	
Descriptive analysis		•
Ranking using Aggregation	•	
Coherent relation across scales for scenario analysis		•

The two models can be considered having a common framework based on a process of learning based on the integration of qualitative and quantitative analyses for a better understanding of both the problem and the area under investigation. A learning process combines the exchange of the social actors' knowledge with that of experts to provide new conceptual frameworks and to enable reflection, feedback, decision and action planning. In the MuSIASEM approach the social actors' knowledge is used for the variables' specification and parameterization (i.e. participatory analysis for parameter setting and calibration) through a process of data collection (during the investigation phase). The social actors' knowledge is also used in MuSIASEM for the definition of the main categories useful for the representation of the system under investigation.

In the SMCE, the social actors' participation is used all the way through the steps of the analysis, including also the evaluation phase (i.e. participatory analysis for scenarios' identification and evaluation).

In addition, the MuSIASEM approach makes it possible to generate relations of coherence between the variables across different scales. This feature is particularly significant in the analysis of different scenarios of development since it enables to complement information generated in different scientific fields often referring to description of the system obtained on different levels. The latter feature makes the discussion of possible scenarios easier.

As we can see from table 2, the simultaneous implementation of the two methodologies allows for the integration of multidimensional and multi-scale analyses together with participatory approaches. This possibility appears to be particularly suitable for sustainable development assessment, as it should facilitates policy planning and decision making.

2.5 Putting the pieces together in practice: two case studies

This section introduces the main aspects that characterize the two case studies carried out for the analysis of the sustainability of different patterns of agricultural production and of rural development policies. As specified before, the case studies refer to rural areas located in Italy and China respectively.

The first case study refers to the analysis of the sustainability of different agricultural practices performed at the farm level and of the effectiveness of CAP policies to achieve sustainability goals in the area of study.

The second case study refers to the analysis of the sustainability of different patterns of agricultural land use and in relation to different household typologies. It also provides an analysis of the multidimensional consequences of rural-urban migration strategies called for by national, regional and local rural development policies.

The methodologies utilized have been the SMCE, applied in both cases, and the MuSIASEM approach applied only in the Chinese case study. Even though, in both cases, the integrated approach performed has been useful for the analysis of sustainability from a multidimensional perspective, the simultaneous use of the two approaches, in the case of China, have made it possible to establish coherence relations among different scales and to set up benchmark values useful to check the quality of the descriptive representation of the system under investigation. The simultaneous utilization of the two methodologies, in the

Chinese case study, was fundamental for the following major problems experienced during the investigation phase of the research: (i) the complexity of the Chinese reality under investigation; (ii) the difficulty to define clearly the problem under investigation; (ii) the difficulty to deal with imprecise information. On the contrary, in the Tuscany case study, the problem under investigation was clearly identified, the information was easier to collect and the reality under investigation was characterized by less complexity.

2.5.1 The Tuscany case study: integrated analysis of different patterns of agricultural cultivations under soil erosion

This case refers to a field study, conducted in a small rural area in southern Tuscany, which was performed to evaluate the sustainability of farming practices in the presence of the soil degradation phenomena due to the adoption of a monoculture of durum wheat. A major concern of the analysis is the comparison of conservative and conventional durum wheat cultivation practices, in terms of their economic, environmental and social performances. The final result sheds light on the various multidimensional consequences related to the adoption of one or the other cultivation practice paying special attention on the soil erosion phenomena. Additionally, the study analyses the influence of agricultural policies (such as the CAP-Common Agricultural Policies) on the management of farming practices and as a consequence, on the soil erosion process.
The methodology used is the SMCE.

Table 3 Methodology used and analyses performed in the Tuscany case study

Models / **Features**	**SMCE**
Multidimensional analysis	•
Participatory analysis for parameter setting and categories identification	
Participatory analysis for scenarios' identification and evaluation	•
Normative analysis	•
Descriptive analysis	
Ranking using Aggregation	•
Coherent relation across scales for scenario analysis	

2.5.2 The Chinese case study: integrated analysis of "rural-urban migration" policy with respect to different patterns of agriculture and typologies of household

This case refers to a field study conducted in a rural village of China, Hongxing village, located in the southern east part of Chongming island.

The investigation explores the impacts and trade-offs of urbanization strategies called for by rural development policies in a selected rural village of China, Hongxing. This is done by the use of a multi-scale integrated framework, based on SMCE and MuSIASEM approaches, which is applied to compare the environmental, social and economic performances of different typologies of households and of urbanization related land use scenarios. The integrated analysis is performed by means of the selection and evaluation of multidimensional criteria, which are representatives of the main goals of development policies in the area of study (increasing the income per capita, reducing the human pressure on the environment, improving the social condition of the rural population).

The evaluation of the scenarios is carried out at two different levels, village and households. At the village level, the metabolism of the land use systems resulting from the rural-urban migration policies is analyzed based on a comparative study considering at once their biophysical and socio-economic performances. At the household level, the environmental, economic and social performances of different household typologies (off-farm, on-farm and partially off-farm) are compared based upon evaluation criteria selected in relation to the main goals of development policies in the area of study.

The methodologies used are SMCE and MuSIASEM.

Table 4 Methodologies used and analyses performed in the Chinese case study

Features \ Models	SMCE	MuSIASEM
Multidimensional analysis	•	•
Participatory analysis for parameter setting and categories identification		•
Participatory analysis for scenarios' identification and evaluation		
Normative analysis	•	
Descriptive analysis		•
Ranking using Aggregation	•	
Coherent relation across scales for scenario analysis		•

3 [9] SOCIAL MULTI-CRITERIA EVALUATION OF FARMING PRACTICES IN THE PRESENCE OF SOIL DEGRADATION. A CASE STUDY IN SOUTHERN TUSCANY, ITALY

[9]This chapter of the thesis builds on the paper of the same title published in the Journal of Environment, Development and Sustainability in August 2008, (Siciliano, 2008).

Summary

This chapter of the thesis analyses the financial, environmental and social aspects of durum wheat cultivation practices linked to soil degradation processes in Southern Tuscany. The analysis has been conducted within a Social Multi-Criteria Evaluation (SMCE) framework and utilizing NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) as a software tool. Conventional, integrated and organic durum wheat cultivation practices have been compared. One key outcome of the analysis is that organic practices represent a good compromise solution in relation to the environmental and socio-economic evaluation criteria chosen. Finally, the chapter also offers some considerations regarding the influence of Agricultural European Policies (such as the CAP-Common Agricultural Policy) on the management of farming systems and as a consequence on the soil degradation phenomena.

3.1 Introduction

The processes of the Earth's soil degradation encompass a wide range of phenomena, ranging from natural geological erosion processes and accelerated erosion[10] (Gisotti, 1991; Giordani and Zanchi. 1995; Lal, 1991; Toy et al., 2002) to extreme degradation processes such as desertification[11].

The remarkable variety of soil functions (food and other biomass production; storage of energy, filtration of water and transformation of minerals, organic matter and various chemical substances; habitat for a huge number and variety of organisms; physical and cultural environment for mankind, source of raw materials) are continuously under threat from various types of soil degradation: water and wind erosion, decline of nutrients or organic matter, local and diffuse pollution, water-logging, compacting and salinisation[12] (Oldeman et al., 1991).

One of the first references to the Earth's soil degradation comes from the United Nations Conference On Desertification (UNCOD) held in Nairobi in 1977. The conference identified "the prevention of soil degradation in areas compromised by over-production" as a priority underlining the relationship between the Earth's soil degradation and socio-economic development. However, the first substantial acknowledgement of the Earth's soil degradation problem emerged from the United Nations Convention to Combat Desertification (UNCCD), which was adopted in Paris in 1994 and signed by more than 100 countries, coming into force in 1996, when it was sanctioned by 174 states. Italy ratified the convention in 1997. Currently 185 States are party to the Convention (as of April 2003).

Europe (and therefore also Italy) developed intervention plans (NAP – National Action Programmes) to monitor, prevent and alleviate the soil degradation phenomena, in favour

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[10] Accelerated erosion causes a faster decay of physical and structural characteristics of the superficial soil layer reducing considerable soil fertility and productivity.

[11] According to the United Nations Convention to combat desertification (UNCCD), desertification means land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climate variations and human activities. While, land degradation means reduction or loss of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland or range, pasture, forest and woodlands, resulting from land uses or from a process of combination of processes, including processes arising from human activities and habitation patterns. Definitions available at http://www.unccd.int.

[12] According to the GLASOD (Global Assessment of Soil Deterioration) classification (Oldeman, 1991) water erosion and wind erosion are defined as a decrease in depth of the topsoil layer due to more or less uniform removal of soil material by run-off water and by the wind. Soil degradation is due to pollution as a consequence of location, concentration and adverse biological or toxic effects of a substance. The covering of the soil by infrastructure, roads or other uses takes the name of water-logging. The water-logging reduces the available surface for the development of the soil functions, between which the absorption of the water for infiltration, causing water erosion phenomena. The soil compacting is the deterioration of soil structure by trampling, by cattle, or the weight and/or frequent use of machinery. Salinisation is the net increase of the salt content of the top soil leading to a productivity decline.

of sustainable land management. Italy was the second Mediterranean European country to adopt the NAP to combat drought and desertification.

Looking at the anthropogenic factors of soil degradation in particular, agricultural activity is considered to be the main culprit (Jetten et al., 1999; Kosmas at al., 1999). For a long time agricultural practices have been based on the notion of soil as an inexhaustible resource. Due to its very slow formation rate however, soil must be considered as a non-renewable resource and should be protected (Lal, 1991). Sustainable agricultural soil use has the function of maintaining soil fertility. In general, agricultural practices that can be considered as having a negative effect on soil conservation are related to an increase in intensive farming and mechanization, excessive use of pesticides and fertilizers, the diffusion of monoculture systems and deforestation. On the other hand, sustainable agricultural practice takes into consideration the physical and structural characteristics of the soil together with the balance of the ecosystem, guaranteeing an optimum soil management. The agricultural sector in all its complexity has a fundamental role in soil conservation and the processes of degradation (Toy et al., 2002). Therefore, planning of interventions in agricultural production activities constitutes a fundamental part of sustainable land use planning.

Several studies have been developed regarding sustainability evaluation in rural areas (Lopez-Ridaura et al., 2005; Sands and Podmore, 2000; Van der Werf and Petit, 2002). However, very few examples of existing studies focus on the development of practical tools to support policy making. Such tools would be particularly useful for analysing the influence of agricultural policies on the management of farming practices and for designing policy interventions in favour of a sustainable land management (Pacini et al., 2002).

This research refers to a field study, conducted in a small rural area in southern Tuscany, which was performed to evaluate the sustainability of farming practices in the presence of the soil degradation phenomena due to the adoption of a monoculture of durum wheat. A major concern of the analysis is the comparison of conservative and conventional durum wheat cultivation practices, in terms of their economic, environmental and social performances. The final result sheds light on the various multidimensional consequences related to the adoption of one or the other cultivation practice, paying special attention to the soil erosion phenomena. Additionally, the study analyses the influence of agricultural policies (such as the CAP-Common Agricultural Policies) on the management of farming practices and as a consequence, on the soil erosion process.

A Social Multi-Criteria Evaluation (SMCE, Munda, 2004) is employed as a general framework to evaluate both the multidimensional aspects of the alternatives and the impact of agricultural policies on soil erosion.

As stated above, SMCE can be defined as a learning process that combines a type of MCA (Multi-Criteria Analysis) with institutional and social analyses.

Some of the dominant characteristics of the SMCE are its inter/multidisciplinarity, transparency and capacity to include participatory instruments: inter/multidisciplinarity refers to the possibility of analysing the problem at hand considering the various points of view of diverse disciplines. Transparency permits one to express all the evaluation criteria according to their own units of measurement, which means no transformation into a unique commensurate value is needed (e.g. monetary values). Finally, it enables the inclusion of the local community, and thus making it possible to make the evaluatioj process more democratic.

These characteristics are very important when dealing with agricultural systems that are complex in nature. Considering farming systems as complex systems, it becomes impossible to describe them exhaustively with a set of assumptions typical of any single scientific discipline. Representing this complexity necessitates applying assessment of several hierarchical levels and various dimensions using a multi-scale analysis approach (Giampietro, 2004).

3.2 The Evaluation Process: Methodological Foundations and Operational Steps

As mentioned in the introduction, the evaluation process for the Tuscany case study, was based on using the SMCE as a general framework. The methodological foundations of the SMCE are related to the concepts of 'reflexive complexity' and 'incommensurability'. The capacity of a system to adapt to the presence of new attributes and values to be considered can be called 'reflexive complexity'. An example of this is the human system which adds new relevant qualities/attributes all the time that need to be considered when explaining, describing or forecasting its behaviour (the so-called learning systems) (Munda, 2005).

These observations can also be synthesised in the concept of weak comparability (Martinez-Alier et al., 1998) which implies the existence of both technical and social incommensurability in the real world.

Social incommensurability refers to the presence of different legitimate values which cannot be synthesised in a single value and therefore must be represented as much as possible in the analysis, whilst also considering that the various parties involved with different interests, cultural identities and goals, have different definitions of the same value (O'Neill, 1993).

Technical incommensurability refers to the multidimensional nature of complexity and therefore the necessity to represent it using different units of measurement.

Therefore, going back to the concept of sustainability in agricultural systems according to Mario Giampietro (2004) "[…] agricultural systems are complex systems operating on several hierarchical levels. This makes impossible an exhaustive description of them with a set of assumptions typical of a single scientific discipline".

Based on this consideration, the analysis has been conducted making a distinction between the following hierarchical levels: constitutive elements of the farming system level (L0), farming system level (L1), local ecosystem level (L2), and regional level (L3). All the hierarchical levels analysed have the characteristic of being closely connected in terms of nested hierarchies which implies that the elements of a "[…] lower level can combine into new units that have new organizations, functions, and emergent properties" (Gibson et al., 2000) and thus forming a higher level of organization.

This type of structure implies that decisions taken at one level indirectly influence other given levels too. For instance, the implementation of protected areas and natural reserves directly influences the organization of the level L2 and indirectly the level L1. The CAP's agri-environmental measures, while directed at regional politics, indirectly influence the choices of the farmers driving them towards one or the other agricultural practice.

In this context, a social multicriteria evaluation seems to represent an excellent framework of analysis since it allows one to consider different goals in a multidimensional perspective, representing the characteristics of each system without necessarily reducing the analysis to a single point of view or value[13].

At the same time, the SMCE, through the use of participation, enables one to consider the points of view of all the parties directly involved in the decision making process.

Using the concepts outlined, this study has implemented a process of participation with the aim of including, as far as possible, all the differing points of view of the parties involved in the problem.

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[13] The most commonly used tool to evaluate all consequences of a decision in the context of sustainable development is the so-called 'cost-benefit analysis', which is based on the evaluation of the effects of an act by means of a single unit of measurement, the monetary valuation (Bresso, 1996). Multicriteria analysis was created to avoid this kind of reductionism, since it allows defining a ranking among the alternatives leaving all criteria in their own unit of measurement (Janssen and Munda, 1999).

Following the SMCE, the phases which allow the definition of both the alternatives and the evaluation criteria and to subsequently obtain the final rank, are the following:

1) Institutional analysis;
2) Identification of the main parties involved;
3) Formation of Alternatives and Evaluation Criteria;
4) Data Collection and Quantitative Research;
5) Criteria aggregation;
6) Sensitivity analysis;
7) Interpretation of results.

3.3 The case study area and the erosion processes

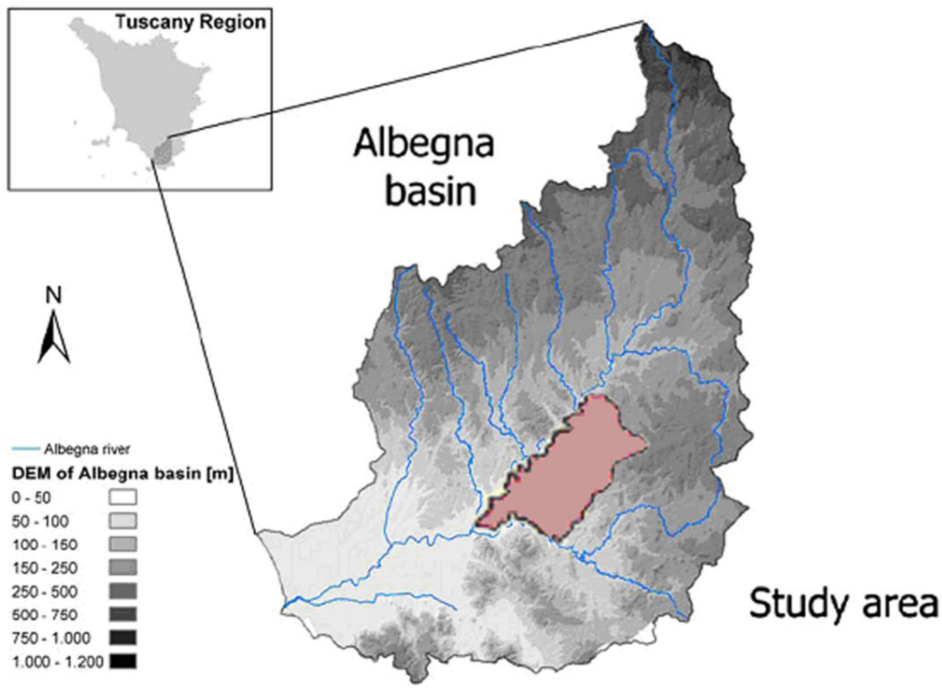


Figure 6 Tuscany Region, Albegna river basin and study area [CRES elaboration]

The case study area is located in the southern part of Tuscany in the lower valley of the Albegna river basin (figure 6). The choice of the study area has been dictated by the information availability concerning the soil structure and by the presence of erosion forms

(Angeli et al., 2004; Marker et al., 2008) that can be considered as characteristics for the whole Albegna river basin[14] area (see figure 7).

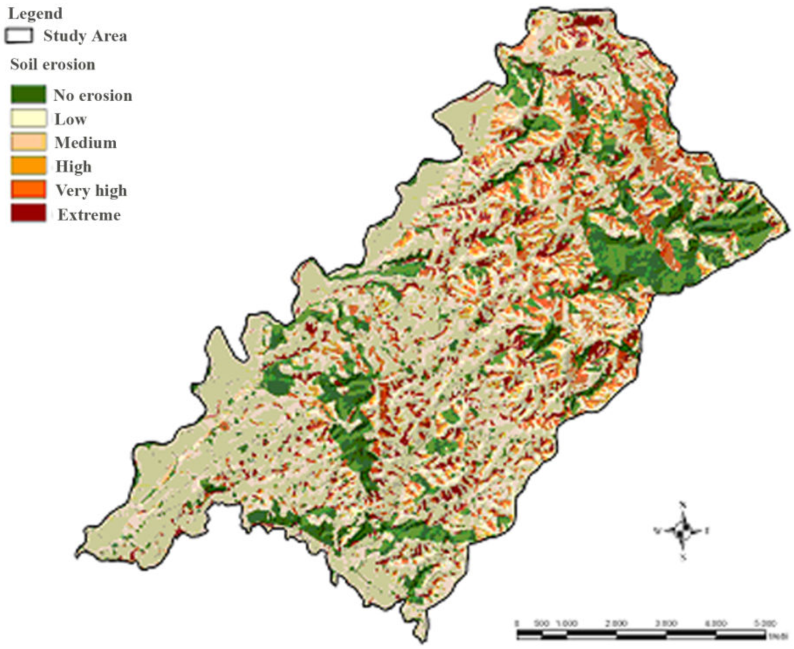


Figure 7 Map of the processes of erosion in the study area [CRES elaboration]

In particular, the study area covers a surface of about 7500 hectares (75 sq.km). It is located within the administrative territory of Manciano, one of the municipalities within the Albegna river basin[15]. Looking at the demographic characteristics of Manciano (table 5), we can state that the elements which characterize the area are in brief:

- low population density;
- a declining number of residents;
- an ageing population and a high dependency rate of the elderly generation compared to the younger generation.

These characteristics weight heavily on the economic development of the area. Local firms are small, with poor links with the rest of the territory. The main economic sector is agriculture in terms both of number of firms (figure 8) and employees.

[14] For more information on the methodologies used for the identification of the erosion forms see Angeli (2004) and Marker et al. (2008).
[15] In particular, the Albegna river basin is divided into the following municipalities: Arcidosso, Capalbio, Magliano in Toscana, Manciano, Orbetello, Roccalbegna, Santa Fiora, Scansano, Semproniano.

Furthermore, the Region of Tuscany classifies the area (the Albegna river basin and as a consequence all the related municipalities, including the study area) as a ‘rural-marginal’ area, characterized by an ageing population and high unemployment, where there are few opportunities outside the agricultural sector.

Table 5 Demographic indicators. Municipalities of the Albegna river basin, Tuscany and Italy

Demographic indicators	**Italy**	**Tuscany**	**Magliano in Toscana**	**Manciano**	**Orbetello**	**Roccalbegna**	**Scansano**	**Semproniano**
Birth rate	9.44	8.12	5.34	4.79	6.63	4.87	7.74	5.48
Death rate	9.78	11.50	10.93	11.70	10.57	18.28	15.66	17.48
Net migration rate (2000)	6.08	5.34	0.00	43.00	-20.00	6.00	21.00	8.00
Population change	5.74	1.96	-5. 59	36.09	-23. 94	-7. 41	13.08	-4.00
Elderly population	123.74	191.91	273.31	303.42	194.91	420.91	318.50	538.04
Youth index	18.56	16.31	16.71	15.20	16.15	12.30	15.03	11.44
Index of demographic dependency	47.46	51.93	53.76	60.62	51.02	79.58	60.00	79.11
Index of economic dependency	26.25	34.14	39.36	45.59	33.72	64.31	45.66	66.71
Old people composition	137.45	107.37	129.35	106.46	114.21	90.91	107.51	89.20
Old people /population	17.61	22.47	25.60	28.39	22.33	35.81	28.54	37.25
Population density	189.14	152.07	15.00	18.00	64.00	10.00	16.00	16.00

Source: Elaborations based on Istat data, population census data 2001

Legend:
Birth rate: [(born)/ (total population)] x 1000
Death rate: [(death)/ (total population)] x 1000
Net migration rate: [(immigrants)/ (total population)] x 1000-[(migrants)/ (total population)] x 1000
Population Change: (difference between birth rate and death rate ± net migration rate)
Elderly population: [(P65 and further on)/ (P0-14)]] x 100
Youth index: [(P15-29)/ (total p)] x 100
Index of demographic dependency: [(P65 and further on +P0-14)/ (P15-64)]] x 100
Index of economic dependency: [(P65 and further on)/ (P15-64)]] x 100
Old people composition: [(P65-74)/ (P75 and further on)] x 100
Old people /population: [(P65 and further on)/ (total population)] x 100

Manciano statistical data shows that the highest number of firms in the area is in the agricultural sector, representing 32.2% of those present in the whole basin (Istat, 2001). Agricultural production is divided as follows: 51% arable crops, 4% arboriculture for wood production, 3% permanent grassland and pasture and 26% of woodlands (Istat, 2001). Results from stereoscopic photo interpretation and aerial evaluation techniques of the study area show that 67% of the total area in hectares are included under the soil use class of ‘arable crops and permanent grassland and pasture’ (Angeli et al., 2004).

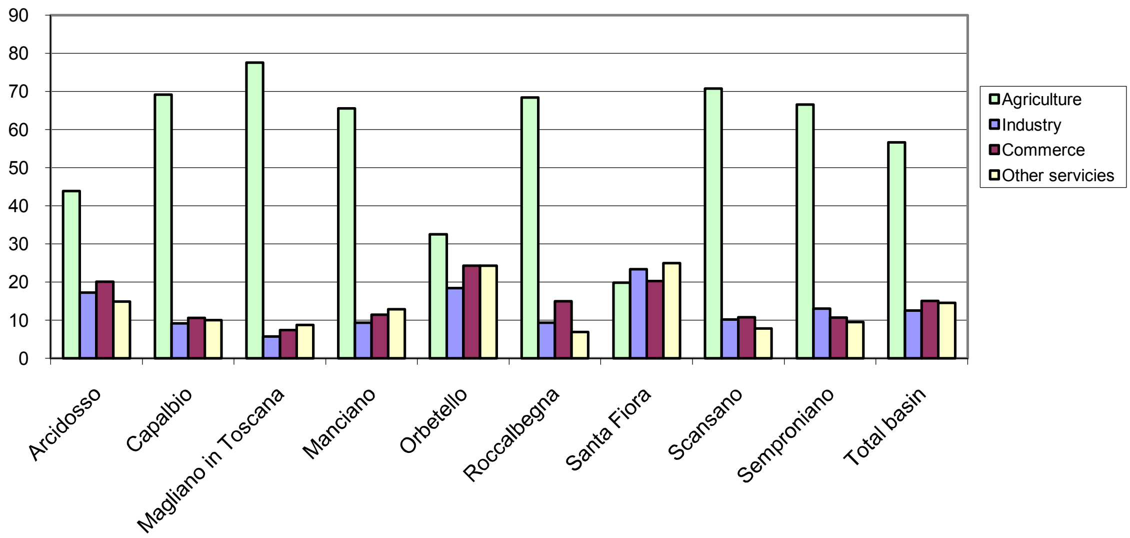


Figure 8 Firms per economic sectors year 2001 (per cent values) - municipalities of the Albegna river basin

Results from a questionnaire (see questionnaire 2 in the appendix related to this chapter) that was used to collect technical data on a sample of 22 farms (chosen according to their geographical position, assuring an even distribution in the study area) revealed that durum wheat is the main crop cultivated with no provision of soil preservation rotation plans. This conclusion has been supported by repeated observations in the field carried out in cooperation with the technicians of the rural development services and rural technicians working with farmers.

These analyses made it possible to identify the practice of conventional durum wheat agriculture (without the realization of conservative rotation plans, i.e. monoculture practice) as the main anthropogenic cause of the erosion in the area.

3.4 The institutional analysis and the participatory process

Understanding the cultural, legal, administrative and political context which influence the problems the analyst is going to investigate, as well as identifying the main characteristics of the given case study, are the objectives of an institutional analysis (Dente et al., 1998; Ingram et al., 1984; De Marchi et al., 2000). This analysis is performed based on various sources of information (i.e. newspapers, publications, formal and informal documents, current legislation, historical documents, census), and in two main steps. The first step is concerned with the definition and characterization of the problem at hand. The second step is related to the identification of the main social actors that are closely interlinked with the problem. The study of the actors is a basic issue in an institutional analysis and it is carried out based on the analyst's observations and understanding of the main aspects of the problem under investigation.

In this particular case-study various sources of information were used to perform the institutional analysis. The following sources were analysed:

- European (CAP-Common Agricultural Policy), national (NAP-National Action Programmes to combat soil degradation and desertification) and regional (Rural Development Plan) policies and guidelines related to the management of agricultural areas;
- the current European, national and regional legislation related to the management of agricultural areas;
- local information collected from the main municipalities of the Albegna river basin (formal and informal documents, mainly internal publications);
- historical evolution of the area (historical publications);
- statistical data regarding the socio-economic situation (Istat, 2001).

According to the institutional analysis, the main parties involved in taking steps to prevent the processes of soil degradation in the area have been identified as follows:

- Provincial administration;
- Municipal administration;
- Regional administration;
- Agricultural associations;
- Farmers;
- ARSIA (Regional Agency on Development and Innovation in Agriculture);
- Environmental associations.

The above-mentioned actors intervene directly or indirectly to determine rural development policies in the study area. In particular, regional, provincial and municipal administrations intervene, dictating the strategies of the development of the area, taking into consideration the European and National guidelines related to rural development. They also intervene directly with the concession of subsidies to farmers. The ARSIA provides technical support to farms and is responsible for innovation projects and experiments carried out in the area. The agricultural associations, working in conjunction with the farmers, significantly affect territory management choices at the farm level. Environmental associations are involved by organizing courses on environmental education for farmers. The parties concerned have been involved in the process of determining both management alternatives and the evaluation criteria through the realization of a participatory process. This process was handled using the following instruments:

- Questionnaires[16];
- Telephone interviews;
- Face to face interviews.

Local people and institutions were contacted for the following reasons:

a) To gather information regarding the common uses of the soil in the study area and the farmers' perception of the erosion processes;
b) To gather information regarding local people's needs and expectations;
c) To gather information regarding goals and priorities of the institutions (agricultural associations, municipal and provincial administrations, ARSIA, environmental associations) for the rural development of the area;
d) To collect data for the criteria evaluation.

In order to gather information regarding both the common uses of the soil and farmers' perception regarding the erosion process, questionnaires were distributed to 22 farms located within the study area. Telephone and face to face interviews were conducted with all the other social actors (mainly from the local government): agricultural associations (3 formal interviews with agricultural technicians and more than 10 telephone and informal contacts for each of three agricultural associations, Coldiretti, Confederazione Italiana Agricoltori and Confagricoltura), municipal and provincial administrations (4 face to face interviews and 2 telephone interviews with the main municipal and provincial

[16] Selected questionnaires can be found in the appendix. The other questionnaires and all of the results of the participatory process are available from the author upon request.

representatives), ARSIA (2 telephone interviews with technicians), environmental associations (2 face to face interviews and 4 telephone interviews, for each of two environmental associations, WWF Italia and Legambiente) to obtain information regarding the institutional rural development goals and priorities. Finally, questionnaires and interviews with 8 farms were held to collect data for the criteria evaluation.

The questionnaires are of a mixed type (open, closed and semi-open-ended questions) and the information collected was both qualitative and quantitative.

Results were used for the generation of the alternative options and of the evaluation criteria.

3.5 Generation of alternatives

Taking into account the main parties involved in the problems of soil erosion in the study area and from the results of the institutional and participatory analysis, three types of alternatives of agricultural cultivation practices have been identified (see table 6):

1) '*Conventional cultivation practice (CCP)*' – the usual agricultural techniques adopted in the study area.
2) '*Organic cultivation practice (OCP)*' – introduction or maintenance of organic agricultural methods.
3) '*Integrated cultivation practice (ICP)*' – reduction in the use of fertilizers.

The first cultivation practice type represents the current agricultural practice in the study area, characterized in particular by durum wheat cultivation without the use of conservation rotation plans, has been identified as the main cause of soil erosion problems in the study area. The second comes from the institutional analysis. Soil conservation policies at European, national, regional and local levels in fact consider organic agriculture as a practice that significantly reduces the processes of soil degradation. Moreover, in answer to the question "How could soil conditions be improved?" local people and farmers to a large extent, answered citing organic agricultural practices. It is widely recognized that organic agriculture, as a low environmental impact agricultural practice, is based on the realization of rotation plans according to the soil's physical and structural characteristics, supporting the continuity of biodiversity and compacting the superficial soil layer, thus preventing or reducing the erosion process. The third type comes from territorial policy guidelines and local people's responses to questionnaires and in-depth interviews.

Table 6 Overview of the alternatives

Alternatives	Description
CCP-Conventional Cultivation Practice	Conventional practice represents the usual agricultural technique adopted in the study area. It is characterized by the practice of agriculture with no environmental protection in place. Crop rotation is rare (not year by year) and is based on species that do not have the characteristics to increase ground fertility (such as mixed grass). Finally, just a small amount of cultivation residues is left in the soil.
OCP-Organic Cultivation Practice	Organic practice meets the requirements of the organic farming code following measure 6.2 of the EU Regulation 1257/1999. Organic practice pays attention to soil conservation. It carries out a series of crop rotations which assures the presence of organic matter and nitrogen, ploughing is more superficial and cultivation residues are partly or completely left in the soil. These practices have the benefit of increasing ground fertility. Usually, the organic farming, generates a lower yield in comparison to both conventional and integrated systems.
ICP-Integrated Cultivation Practice	Integrated practice meets the requirements of the integrated farming code with the reduction in the use of fertilisers. In particular, it meets the requirements of the integrated farming code of the EU Regulation 2078/92 Tuscany Region agri-environmental enforcement programme (updated by the 2000-2006 Tuscany Region Rural Development Plan (TRRDP), which enforces the EU Regulation 1275/1999). However, crop rotation is rare (not year by year) and is based on species that do not have the characteristic to increase ground fertility (such as mixed grass). Just a small amount of cultivation residues is left in the soil. The integrated farming system, with a reduction in the use of fertilizers, suffers a lower yield in comparison to conventional systems but more than organic.

3.6 Identification of the evaluation criteria and criterion scores

The identification of the evaluation criteria, as with the choice of the alternatives, comes partly from the results obtained from the in-depth study of the area (historical and current situation analysis, institutional analysis) and the expectations of the local people and farmers and partly from the main aim of this research (the study of erosion problems). Therefore, on the basis of the participatory process, and taking into consideration the soil degradation problems which have to be analyzed in such a context, the evaluation criteria have been put together considering three main aspects: economic, environmental and social (see table 7 and 8).

Table 7 Identification of the evaluation criteria according to the stakeholders' priorities

Criteria		Social actors (local people, farmers)	Institutional actors (administrations, agricultural and environmental associations, ARSIA)	Main aim of the research (study of erosion problems)	Problems emerged from the in-depth study of the area
Economic dimension	**GSP**	√			
	Direct costs	√			
Ecological dimension	**Soil erosion**			√	
	Protection of the agricultural landscape	√	√		
	Energy intensity				√
	Soil compacting			√	
Social dimension	**Risk of rural area abandonment**		√		√
	Dependence on community contribution	√			

According to Munda's definitions evaluation criteria are "[…] functions that associates each single alternative with a variable indicating its desirability according to expected consequences related to the same objective". Criterion score "[…] is a constructed measure stemming from a process that represents, at a given point in space and time, a shared perception of a real-world state of affairs consistent with a given criterion" (Munda and Nardo, 2003).

As a consequence, the values that each criterion score gives to each alternative provides information to draw a picture of each alternative through the aims represented by the criteria.

Table 8 Evaluation criteria and criteria score

Dimension	Evaluation criterion	Criterion score
Economic	GSP (Gross Saleable Production)	Entrances from the sale of durum wheat + CAP and agro-environmental measures subsidies [€/ha]
	Direct cost	Direct cost for the growing of durum wheat [€/ha]
Ecological	Soil Erosion	Amount of soil loss in tonnes per hectare in a year [t/ha year^{-1}]
	Protection of the agricultural landscape	Evaluation of the concept of aesthetic and ecological heterogeneity [qualitative evaluation]
	Energy intensity	Energy use expressed in absolute terms [MJ/ha]
	Soil compacting	Number and horse power of the agricultural machinery used [Q/hp]
Social	Risk of rural area abandonment	Combination of three criteria: plural-functionality, farmers' demand for experienced workers, average age of farmers [qualitative evaluation]
	Dependence on community contributions	Dependence of the alternatives on CAP (Common Agricultural Policy) contributions and on agro-environmental measures [qualitative evaluation]

3.6.1 Economic criteria

Taking into account the answers from the questionnaires and in-depth interviews, and the importance of economic factors for farmers and local people, two economic evaluation criteria have been chosen allowing one to evaluate the consequences of the choice of each agricultural practice on a farmers' income. The evaluation criteria chosen are those that are usually used in agricultural economic studies to evaluate agricultural practices. The first is the GSP (Gross Saleable Production), the significance of this evaluation criterion is well known in agricultural economics, it measures the amount of crop yield and the subsidies from the CAP (Common Agricultural Policy) and agri-environmental incentive plans, based on European regulation 1257/1999. The other economic evaluation criterion, is the direct cost for the cultivation of durum wheat. This is the only way to evaluate single crop cultivations, since attributing fixed costs is extremely difficult.

GSP

The gross saleable production is the crop yield multiplied by its price plus public subsidies. In this case the crop yield is durum wheat and the public subsides are those from the CAP reform and agri-environmental measures 6.1 and 6.2[17] (EU Regulation 1257/99).

$$GSP \equiv P \times q + C_{CAP} + C_{6.1} + C_{6.2}$$

Where:
P = price of durum wheat
q = amount of durum wheat yield
C_{CAP} = CAP subsidies for the cultivation of durum wheat
$C_{6.1}$= subsidies for the adhesion to the agri-environmental measure 6.1
$C_{6.2}$ = subsidies for the adhesion to the agri-environmental measure 6.2
The information used for the final calculation of the indicator are as follows:

- information given by the farmers on the yield amount of durum wheat in 2003;
- information given by the agricultural associations concerning the CAP and agri-environmental subsidies;
- information gathered from the Chamber of Commerce concerning the prices of the durum wheat throughout 2003. This information has been used for the calculation of the average price for the final evaluation.

Direct costs

The direct cost entries involved for this calculation are those relative to the cultivation of durum wheat and are the same for all three alternatives considered: fuel, lubricant, fertilizers, herbicides, seeds, and those deriving from the adherence to agri-environmental CAP measures 6.1 and 6.2. Measure 6.1, referring to organic agriculture, involves the following additional costs: checking for infestation using biological instruments, treatment with biological products, analysis and product certification. Whereby CAP measure 6.2,

[17] The chapter VI 'Agri-environment' of the EU Regulation 1257/1999 disciplines the support for agricultural production methods design to protect the environment and to maintain the countryside. Support shall be granted to farmers who give agri-environmental commitments, such as:

- action 6.1: introduction or maintenance of organic agricultural methods;
- action 6.2: introduction or maintenance of integrated agricultural methods.

referring to integrated agriculture, involves: costs coming from the prohibition of ‘reingrano’[18], soil analysis, fertilization plans, record keeping storage and treatment against infestation.

Some of the costs listed above come from information given directly by the farms. Others such as fertilizer, herbicide and seed prices, from information provided by the Agricultural Consortium in Manciano (the largest municipality of the area). Costs concerning the adherence to the agri-environmental measures, come from the Tuscany Region Rural Development Plan[19]. Given the difficulty of evaluating the consumption of fuel and lubricant just for the cultivation of durum wheat, coefficients from existing literature (Piccarolo, 1982) have been used, supported by information as follows:

- the hours employed in the five stages of durum wheat cultivation (ploughing, preparation of the soil bed, sowing, fertilizing, harvest);
- the type of agricultural machinery used.

Using a formula, the calculation of the total fuel and lubricant consumption is obtained for the growing of durum wheat. The formula used to estimate the Hourly Fuel Consumption (HFC) in litres, is the following:

$$HFC \equiv 0.1 \times hp$$

Where:
HFC = Hourly Fuel Consumption
hp = horse power.

The coefficient 0.1 kg/h is the operating average consumption for every hp (Piccarolo, 1982)[20].

For the Hourly Lubricant Consumption (HLC) in litres, the following formula (Piccarolo, 1982) has been used:

$$HLC \equiv 4.5/1000 \times hp$$

[18] ‘Reingrano’ means the cultivation of the durum wheat in the same yield in a short period of time.

[19] The Tuscany Region Rural Development Plan (TRRDP) provides an estimation of the effects of agri-environmental measures on the Tuscan farmers income with respect to the generic farms and to the type of cultivation. The data related to the costs for the agri-environmental measures adhesion considered in the study derive from such evaluations.

[20] In the consulted bibliography the coefficient was included in the interval 0.10-0.16 kg/h, the choice of the lower value was defined in consequence of an interview with Professor Piccarolo, author of the book, which, taking into consideration the reduction of the consumption of the modern machinery, advised to use the lowest value.

Where:

HLC = Hourly Lubricant Consumption

The coefficient 4.5 g/h is the average operating consumption per hp (Piccarolo, 1982).

Finally, in order to calculate the costs, the previous results have been multiplied by the hours employed in each stage of durum wheat cultivation and by the average fuel and lubricant prices calculated throughout 2003.

3.6.2 Ecological Criteria

The choice of the ecological criteria comes partly from the aim of this research (the study of erosion problems) and partly from the survey and participatory process mentioned above. Therefore, the ecological evaluation criteria chosen are: soil erosion; rural landscape protection; energy intensity; soil compacting. In particular, soil erosion and soil compacting, as mentioned above, derive from the main aim of this research regarding soil degradation problems in the study area. Rural landscape protection criteria have been selected according to local people's needs and territorial strategies promoted at the regional and provincial level. In the case of the latter the element which both local people and institutions want to maintain is the heterogeneity of the Tuscan agricultural landscape. In particular, the rural development plan for Tuscany considers two aspects of landscape heterogeneity: aesthetic and ecological. From an aesthetic point of view, soil use heterogeneity is directly proportional to the value which can be attributed to the landscape, " [...] a landscape, within certain limits, tends to be more appreciated since the structure of the various elements which make up its composition is more complex " (Tuscany Region, 2000). From an ecological point of view, a more heterogeneous landscape, with a greater number of soil use types, is characterized by a larger amount of different natural habitats[21]. Since one of the main aims is to evaluate the economic, environmental and social sustainability of different agricultural practices, an energy intensity criterion has been chosen to complete the analysis. Such a criterion allows one to evaluate the amount of incoming energy in the agricultural production process. Finally, a soil compacting criterion has included in order to analyse the influence of the machinery use on soil degradation.

[21] Aesthetic and ecological heterogeneities were evaluated using two sub-criteria, respectively: dynamism of the elements of the landscape (mainly crop rotations) and realization of soil conservation practices (crop rotations, fertilizers use, ploughing). The qualitative categories used go from very high to very low. The final evaluation depends on the capacity of each alternative to satisfy the sub-criteria. This capacity is expressed using "+" and "–" signs, the sum of the signs (a "-" cancels out a "+") gives the final qualitative evaluation on the basis of the percentage of the "+" signs obtained.

Soil erosion

Soil erosion has been evaluated through the use of the Wischmeier and Smith universal equation (Wischmeier and Smith, 1978), known as RUSLE (Revised Universal Soil Loss Equation), this equation allows for the evaluation of the soil loss in tons per hectare and year due to interrill and rill erosion processes (see Marker et al., 2008).
The RUSLE equation is as follows:

$$A \equiv R \times K \times LS \times C \times P$$

Where:
A = soil loss [t ha^{-1} $year^{-1}$];
R = rainfall erosivity factor;
K = soil erodibility index;
LS = slope length factor;
C = land cover and management factor;
P = support practice factor.

The values attributed to each alternative derive from the RUSLE application modifying the C-factor (land cover and management factor) considering the different crop rotations and the management of crop residues (Angeli, 2004; Marker et al., 2008). Two different C-factors have been calculated (see table 9), one in relation to the organic practice and one for both conventional and integrated practices, based on the values commonly used in the literature (Giordani and Zanchi, 1995; Marker et al., 2008) and adapted according to the farm management information collected in the field.

Table 9 C- factor values for durum wheat in the study area

Land use	C-factor
Agricultural land conventional/integrated /organic	0.12/0.12/0.07

Energy intensity

The "energy intensity" is given by the energy required for the cultivation of durum wheat considering direct and indirect inputs in absolute terms. The purpose of the criterion is to produce a measure of energy intensity in farming practices. The information used for the calculation of the criterion score are those from Jarach, 1985[22] (such as the primary energy contents of the direct and indirect inputs), and from farmers (see questionnaire 2 in the appendix to chapter 3). Direct inputs include fuel and lubricant consumption. Indirect inputs include: the amount of fertilizers and the amount of seeds. Results of the energy intensity for each alternative are available in the following table.

Table 10 Energy Intensity (2003)

	Energy content (MJ/kg) (Jarach, 1985)	Conventional practice (MJ/ha)	Integrated practice (MJ/ha)	Organic practice (MJ/ha)
INPUTS:				
Machinery operations				
Fuel	46.2	5,441.6	5,373.8	4,594.6
Lubricant	84.0	445.2	439.7	375.9
Fertilizers				
Nitrogen	73.5	5,746.0	4,036.1	0
Phosphorus	13.4	744.5	786.6	0
Potassium	9.2	0	0	0
Seeds	13.9	3,153.6	3,111.4	3,180.2
Herbicides	126.0	16.8	0	0
TOTAL INPUT		**15,547.8**	**13,747.7**	**8,150.7**

Soil compacting

This criterion permits the evaluation of soil compacting due to the use of farm machinery. In the absence of direct data concerning the level of compacting a 'proxy' indicator, which expresses the 'traffic' of farm machinery through their number and horse power, has been used. The number of machines allows one to consider the density of the use of agricultural

[22] Marta Jarach in her article presents an analysis of different sources related to the calculation procedures of the energy conversion factors in agriculture, and in the light of these she suggests the use of some factors considering the characteristics of the Italian agricultural system.

machines on the soil surface, while the horse power is connected to the weight and so to the potential damage caused by this on the structure of soil. The formula used (ANPA, 2001) for the above-mentioned evaluation is as follows:

$$SC \equiv hp \times W \times N \times n / S$$

Where:
SC = Soil Compacting
hp = horse power
W = 1.12 Q/hp average weight
N = number of machines
n = number of machinery operations on the soil during the cultivation of durum wheat
S = surface area with the cultivation of durum wheat

Table 11 Soil compacting

	Number of tractors	Average horse power of the tractors	average weight (Q/hp)	Machinery operations	SC/ha
Conventional	3	92.67	1.12	5	32.22
Integrated	3	91.56	1.12	5	29.04
Organic	3	97.67	1.12	4	10.94

3.6.3 Social criteria

The first significant problem that emerges for the social analysis is that of occupation. Most problems related to the study area's depopulation and unemployment. Analysing the data from the agricultural census, 94% of farms are family-run. The documents, concerning the rural development of the area, show the presence of a SEL (Local Economic System) characterized by a rising ageing population rate and high unemployment. In addition, the area under investigation has been classified by the European Union as a less favoured area in danger of abandonment of land-use (figure 9).

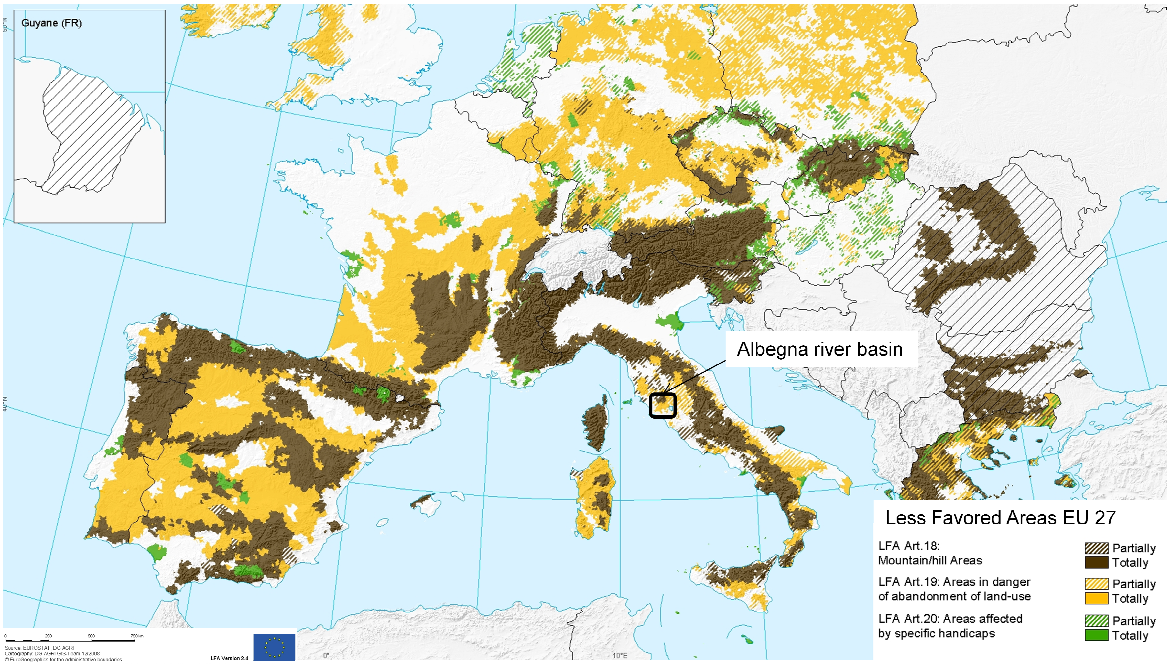


Figure 9 Less favored areas EU 27. Source: European Commission, Agriculture and Rural Development: http://ec.europa.eu/agriculture/rurdev/lfa/images/map_en.jpg

One of the social evaluation criteria therefore is 'risk of rural area abandonment', as a possible link between the abandonment of the area and job opportunity problems. This indicator facilitates the evaluation of job opportunities indirectly (using sub-criteria), through both the concept of plural-functionality, which is the capacity of the alternatives to develop parallel activities such as 'agriturismo' accommodation (farm holiday properties), preservation of the artistic, cultural and environmental heritage and finally an evaluation of the average age of farmers. These issues are very important in order to analyse the effect of each type of soil management on the processes of rural area abandonment.

The other worrying social aspect is related to the agricultural activities' dependence on CAP (Common Agricultural Policy) subsidies. Therefore it is appropriate to consider the farming system's dependence, in relation only to the durum wheat cultivation specifically, on community contributions. All the social criteria have been evaluated in qualitative terms (table 12) [23].

[23] The methodology used (see note 20) for the qualitative evaluation of the social criteria (see table 12 for the sub-criteria considered) is the same of that used in relation to the agricultural landscape protection criterion.

Tabella 12 Social criteria

Dimension	Evaluation criterion	Criterion score
Social	Risk of rural area abandonment	Combination of three sub-criteria: plural-functionality, farmers' demand for experienced workers, evaluation of the average age [qualitative evaluation]
	Dependence on community contributions	Analysis of the farm returns without subsides [qualitative evaluation]

3.6.4 The impact matrix

The impact matrix (table 13) shows the impact of each alternative on the three economic, environmental and social dimensions. The first column shows the evaluation criteria which have been taken into consideration, relating to the three dimensions (economic, environmental and social); the second column shows the unit of measurement of the evaluation criteria chosen; the third column the direction, if one wants to maximize or minimize the criterion; in the last three columns qualitative or quantitative values with respect to each evaluation criteria chosen.

Table 13 Impact matrix

Evaluation criteria	Measurement unit	Direction	Alternatives		
			CCP	ICP	OCP
GSP	€/ha	Max	900	985	966
Direct Costs	€/ha	Min	241	355	382
Soil Erosion	t/ha year^{-1}	Min	1.78	1.78	1.24
Agricultural landscape protection	qualitative	Max	Very low	More or less high	Very high
Energy intensity	MJ/ha	Min	15,547.8	13,747.7	8,150.7
Soil Compacting	Q/hp	Min	32	29	11
Risk of Rural Areas Abandonment	qualitative	Min	Very high	Moderate	Very low
Dependence on community contribution	qualitative	Min	Very high	Very high	Very high

3.7 Data Collection and description of the farms

This first step helped to establish what was the best methodology for collecting data for the criteria evaluation. Eight farms considered to best represent the current agricultural practices in the study area, were chosen. This selection was made with the help of the Agricultural Associations (Coldiretti and Confagricoltura) who have direct contact with farmers providing them with both technical and fiscal advice. The choice to use data from 8 farms came essentially from the aim to carry out an in-depth study of the actual socio-economic and ecological characteristics of the alternatives, since the erosion problems are closely connected to the agricultural practices at the farm level.
The farms selected are the following: three conventional (A), three integrated (B) and two organic (C).
Altogether they cover an area of 947 hectares, which corresponds to about 13% of the total study area. All the data and measurements have been recorded in 2003 through a questionnaire, and they represent the basic information used for the criteria evaluation. For reasons of privacy each farm is represented by a number.

Type A Farm: conventional

These farms grow durum wheat with no environmental protection measures in place. Data concerning general information about the farms is shown in the following table.

Table 14 General characteristics of the type A farms: conventional

Farm characteristics	1A	2A	3A
Size class (ha)	50-100	20-50	50-100
Total area	54 ha	31.83 ha	67.41 ha
Main cultivation	Durum wheat, 12.00 ha	Durum wheat, 5.50 ha	Durum wheat, 30.97 ha
Secondary Cultivations	Clover-Oats, 25.00 ha Forage, 9.00 hectares Other used, 8.00 ha	Barley, 2.50 ha Oats, 2.55 ha Forage, 13.98 ha Other used, 7.30 ha	Alfalfa, 3.43 ha Clover-oats, 20.25 ha Olive groves, 0.81 ha Vine yard, 0.85 ha Wood, 3.53 ha Other used, 7.57 ha
Crop rotations	Durum wheat mixed grass (oats, clover, vetch)	Durum wheat mixed grass (oats, clover, vetch)	Durum wheat mixed grass (oats, clover, vetch)
Field operation	Ploughing, 45 cm	Ploughing, 30/35 cm	Ploughing, 40 cm
Seeds for durum wheat	Amount: 2 Q/ha	Amount: 2.8 Q/ha	Amount: 2.1 Q/ha
Fertilizers used for durum wheat	Nitrogen: 119.00 kg/ha Phosphorus: 138.00 kg/ha Potassium: 0 kg/ha	Nitrogen: 8.29 kg/ha Phosphorus: 19.91 kg/h Potassium: 0 kg/ha	Nitrogen: 107.24 kg/ha Phosphorus: 8.28 kg/ha Potassium: 0 kg/ha
Livestock	250 Sheep	180 Sheep	180 Sheep
Durum wheat yield	20 Q/ha	25 Q/ha	25 Q/ha
Percentage of soil covered with crop residues	30%	30%	30%

Type B Farm: integrated

These farms also grow durum wheat but have some environmental protection measures in place. In particular, they meet the requirements of the integrated farming code of the EU Regulation 2078/92 Tuscany Region agri-environmental enforcement programme (updated by the 2000-2006 Tuscany Region Rural Development Plan (TRRDP), which enforces the EU Regulation 1275/99). Data concerning the generic information about the farms is shown in the following table.

Table 15 General characteristics of the type B farms: integrated

Farm characteristics	1B	2B	3B
Size class (ha)	20-50	20-50	50-100
Total area	46 ha	33.69 ha	70 ha
Main cultivation	Durum wheat, 22 ha	Durum wheat, 14.13 ha	Durum wheat, 17 ha
Secondary cultivations	Tender wheat, 3 ha Mixed Grass, 11 ha Wood, 6 ha Other used, 4 ha	Tender wheat, 0.48 ha Clover-oats, 11.47 ha Olive groves, 0.40 ha Wood, 4.17 ha Other used 3.04 ha	Oats, 7 ha Mixed grass, 46 ha
Crop rotations	Durum wheat mixed grass (oats, clover, vetch)	Durum wheat mixed grass (oats, clover, vetch)	Durum wheat mixed grass (oats, clover, vetch)
Field operation	Ploughing, 40 cm	Ploughing, 30/35 cm	Ploughing, 25 cm
Seeds for durum wheat	Amount: 2.73 Q/ha	Amount: 1.8 Q/ha	Amount: 4.4 Q/ha
Fertilizers used for durum wheat	Nitrogen: 63.6 kg/ha Phosphorus: 50.0 kg/ha Potassium: 0 kg/ha	Nitrogen: 22.14 kg/ha Phosphorus: 56.58 kg/h Potassium: 0 kg/ha	Nitrogen: 79 kg/ha Phosphorus: 69 kg/ha Potassium: 0 kg/ha
Livestock	140 Sheep 40 Cows	290 Sheep	290 Sheep
Durum wheat yield	13 Q/ha	22 Q/ha	15 Q/ha
Percentage of soil covered with crop residues	30%	30%	30%

Type C Farm: organic[24]

These farms grow durum wheat and have environmental protection measures in place that include the practice of organic agriculture following measure 6.2 of the EU Regulation 1257/1999. Data concerning general information about the farms is shown in the following table.

[24] Farming is only considered to be organic at EU-level if it complies with Council Regulation (EEC) n°1257/1999. Organic farming involves holistic production management systems, for crops and livestock, emphasising the use of management practices in preference of the use of off-farm inputs. This is accomplished by using, where possible, cultural, biological and mechanical methods in preference to fertilisers and pesticides (EEA-Environmental European Agency definition).

Table 16 General characteristics of the type C farms: organic

Farm characteristics	1C	2C
Size class (ha)	100 and further on	100 and further on
Total area	107 ha	498.15 ha
Main cultivation	Durum wheat, 26 ha	Durum wheat, 94,40 ha
Secondary cultivations	Vine yard, 7 ha Olive groves, 3 ha Alfalfa, 8 ha Mixed grass, 46 ha Wood, 17 ha	Oats, 8.50 ha Barley, 4.00 ha Maize, 7.51 ha Mixed grass, 66.30 ha Clover, 8.32 ha Alfalfa, 28.77 ha Permanent grassland and pastures, 28.51 ha Favino, 7.52 ha Wood, 204.00 ha Reforestation, 25.33 ha Vine yard, 11.59 ha Olive groves, 3.40 ha
Crop rotations	Durum wheat, forages, sunflower, vegetables	Durum wheat, forages, sunflower, vegetables
Field operation	Ploughing, 25 cm	Ploughing, 25 cm
Seeds for durum wheat	Amount: 1.59 Q/ha	Amount: 3 Q/ha
Fertilizers used for durum whe	Nitrogen: 0 kg/ha Phosphorus: 0 kg/ha Potassium: 0 kg/ha	Nitrogen: 0 kg/ ha Phosphorus: 0 kg/ ha Potassium: 0 kg/ ha
Livestock	500 Sheep 30 Cows 9 Wild boars	40 Sheep 26 Cows 25 Horses
Durum wheat yield	12.3 Q/ha	10 Q/ha
Percentage of soil covered wi crop residues	50% - 100%	50% - 100%

As it is possible to see, from the above information, the organic practice pays attention to soil conservation. It carries out a series of crop rotations which assures the presence of organic matter and nitrogen, ploughing is more superficial and wheat residues are partly or completely left in the soil. These practices have the benefit of increasing ground fertility. On the other hand, the conventional practice does not adhere to any particular measures regarding the conservation of the soil. Integrated practice meets the requirements of the integrated farming code with the reduction in the use of fertilisers. However, in both the conventional and integrated practices crop rotation is rare (not year by year as in organic practices) and is based on species that do not increase ground fertility (such as mixed grass). Finally, they leave just a small amount of wheat residues in the soil. The integrated farming system, with a reduction in the use of fertilizers, suffers a lower yield in comparison to conventional systems and the organic system's yield is still lower.

3.8 Multi-Criteria evaluation of the alternatives

In order to obtain a final ranking of the alternatives, the criteria must be aggregated by means of a model. Here NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) has been used (Munda, 1995, JRC, 1996). The model allows the analysis of the alternatives providing a final ranking and therefore the best alternative in relation to the evaluation criteria. It is based on the pairwise comparison of alternatives, allowing one to obtain preference indexes on the basis of the number of criteria in favour of a specific alternative and the intensity of the preference according to each criterion. Obtaining the final ranking is subsequently possible thanks to the concepts of strengths and weaknesses of an alternative in relation to one another. To obtain the final result the user intervenes through the definition of some parameters and preference relations between the alternatives. Preference relations indicate the degree of credibility so that an alternative is much better, better, approximately equal, equal, worse and much worse in relation to another. There are two parameters to be defined for the criteria aggregation and they refer respectively to the minimum requirement for fuzzy relations (α) and an operator for the compensation degree determination (τ). The criteria are included in the aggregation procedure only if their credibility indexes are above α. The other parameter (τ) allows one to choose the type of compensation for the case analysed. Compensation means the possibility that a bad performance in relation to a criterion is compensated by a good performance in relation to another criterion. In this analysis a Zimmermann-Zysno operator has been chosen, that allows one to define the degree of compensation, that may range from 0 (minimum compensation) to 1 (maximum compensation). The possibility to choose the compensation degree is of fundamental importance especially in studies where the criteria analysed have equal importance. In this case study a low compensation degree has been used.

Having determined these parameters, the next step is the criteria aggregation through the use of an aggregation algorithm that determines the degree of truth for which an alternative is better, indifferent or worse in respect to another. According to the degree of truth NAIADE formulates a final ranking of the alternatives. An important point that needs to be specified regarding the NAIADE model is that all the criteria have the same weight. As a result, the weight of the dimensions considered in the analysis depends on the number of criteria belonging to each dimension (more information about specific features of NAIADE can be found in Munda, 1995 and JRC, 1996).

3.8.1 Definition of the preference relation

The definition of preference relations is of fundamental importance in order to calculate the credibility indexes, values that go from 0 to 1, which trough an aggregation algorithm allow for a comparison of the alternatives. Preference relations are expressed by the user and are defined by means of six functions that make possible to express an index of credibility of the statements that an alternative is much better $C_{>>}$, better $C_{>}$, approximately equal $C \cong$, equal $C_{==}$, worse $C_{<}$, much worse $C_{<<}$ with respect to another. In this case study such preference relations were evaluated in relation to: GSP, soil erosion, energy intensity and soil compacting. For an example the determination of the preference relations is analysed in relation to the GSP criterion. In this case, to define the value for which an alternative is "much better" than another, the minimum distance is calculated on the values that each alternatives assume according to GSP criterion. The other preference relations are defined on the basis of a percentage (75%, 25%, 5%) according to that minimum distance. In particular:

$$C_{>>} = \min\left[\left|g(A_1) - g(A_2)\right|;\left|g(A_2) - g(A_3)\right|;\left|g(A_1) - g(A_3)\right|\right]$$

Where:

$C_{>>}$ = "much better" preference relation

g (Aj) = GSP in relation to the j alternative

The next table shows the values that the preference relations assume in relation to the GSP criterion following the previous indications[25]:

[25] The other preference relations (worse $C_{<}$ and much worse $C_{<<}$) are not represented in the table because they are the exact opposite of the other ones.

Table 17 Preference relations of GSP criterion - Gross Saleable Production

Preference relations-GSP	Values
Much better $C_{>>}$	19
Better $C_{>}$	14
Approximately equal $C \cong$	5
Equal $C_{==}$	1

Figure 10 shows the calibration of the curve which represents the “much better” (“much worse”) preference relation (red curve). This calibration is obtained by inserting the “much better” value (in this case 19). The other values as a consequence calibrate the curves in relation to the other preference relations (from figure 10 it is possible to see the yellow curve coinciding with the better or worse preference relation). Hence, pairwise comparisons are carried out on the concept of the semantic distance between two functions or in the case of a numeric evaluation of the distance as the difference between the two numbers.

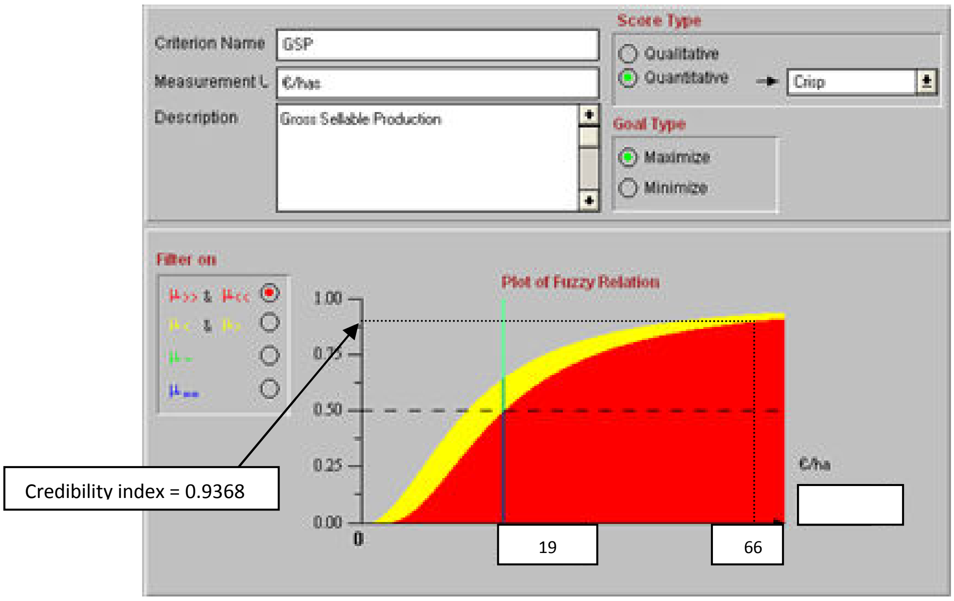
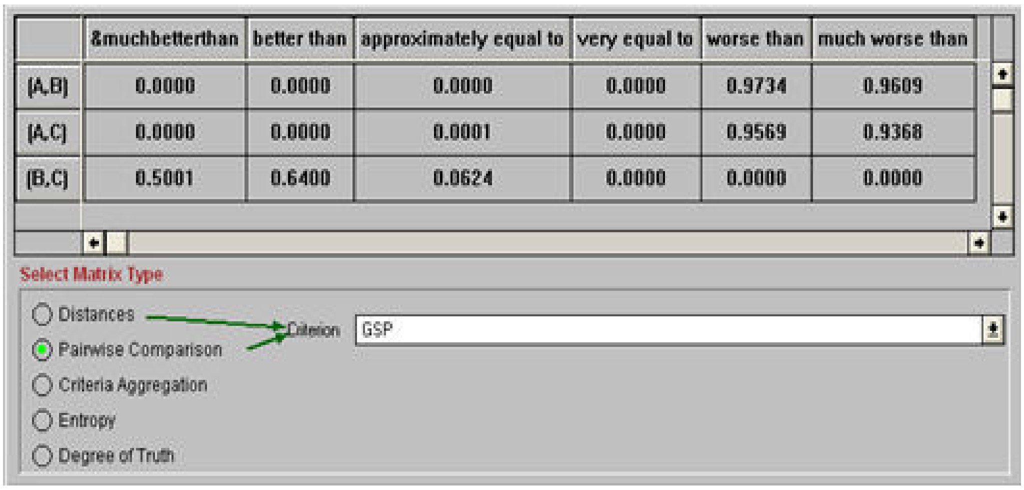


Figure 10 Definition of the GSP criterion and calibration of the curve in relation to the “much better” (“much worse”) preference relation

3.8.2 Determination of the credibility indexes

On the basis of the preference relations defined, the NAIADE software calculates, for each criterion, the indexes of credibility that go from 0 (definitely non-credible that, for instance, alternative a is better than b) to 1 (definitely credible). To do this the concept of distance is introduced. In the case of numeric evaluation the distance is simply the difference between the two numbers. In the case of fuzzy or stochastic evaluation the concept of semantic distance is introduced, that is the distance between two functions. To clarify the concept we can consider again, as an example, the GSP criterion. In this case the difference between the value that the alternative CCP assumes in relation to this criterion and the value in relation to the alternative OCP is equal to 66 (see table 13 for the distance calculation). This distance allows obtaining an index of credibility equal to 0.9368 (see the previous figure) that the CCP option is much worse than the OCP option. Next figure shows the credibility indexes obtained in relation to the GSP criterion in relation to the pairwise comparison related to all the options.



	&muchbetterthan	better than	approximately equal to	very equal to	worse than	much worse than
(A,B)	0.0000	0.0000	0.0000	0.0000	0.9734	0.9609
(A,C)	0.0000	0.0000	0.0001	0.0000	0.9569	0.9368
(B,C)	0.5001	0.6400	0.0624	0.0000	0.0000	0.0000

Figure 11 Credibility Indexes in relation to the GSP criterion

Subsequently the definition of some parameters is necessary for the credibility indexes aggregation.

3.8.3 Definition of the parameters and aggregation algorithm

There are two parameters to be defined for the criteria aggregation and they refer respectively to the minimum requirement for fuzzy relations (α) and an operator for the compensation degree determination (τ). The criteria are included in the aggregation procedure only if their credibility indexes are above α. This parameter has a value that goes from 0 to 1, as with the credibility indexes. The other parameter (τ) allows us to choose the type of compensation for the case analysed. Compensation means the possibility that a bad

performance in relation to a criterion it is compensated by a good performance in relation to another criterion. In other words that means, for instance, that a bad environmental performance can be compensated by a good economic performance and vice versa.
In this case study a Zimmermann-Zysno operator has been chosen that allows to define the degree of compensation, that can go from 0 (minimum compensation) to 1 (maximum compensation). The possibility to choose the compensation degree is of fundamental importance especially in studies where the dimensions analysed have equal importance, as in this case study where it has been decided to use a low compensation degree. Having determined these parameters, the next step is the criteria aggregation through the use of the following algorithm:

$$\mu^*(a,b) \equiv \frac{\sum_{m=1}^{M} \max\left(\mu^*(a,b)_m - \alpha, 0\right)}{\sum_{m=1}^{M} \left|\mu^*(a,b)_m - \alpha\right|}$$

Where:

μ * (a, b) represents the intensity index of preference.

The index obtained plus its correspondent entropy[26] index allows to establish the degrees of truth for which an alternative is better, indifferent or worse with respect to another. According to the degree of truth NAIADE formulates a final ranking of the alternatives (more information about specific features of NAIADE can be found in Munda, 1995 and JRC, 1996).

3.8.4 Evaluation results

Once the impact matrix is constructed (table 13) and the above-mentioned parameters are defined, one can obtain an order of the alternatives.
As mentioned above, in this analysis results are obtained considering a low compensation degree (τ=0.1) and an α parameter (minimum requirement of fuzzy relations) of 0.4.

[26] Entropy is calculated as an index varying from 0 to 1 that gives an indication of the variance of the credibility indexes that are above α and around the crossover value 0.5 (maximum fuzziness) (JRC, 1996).

Taking into consideration all the dimensions, it emerges that OCP alternative (Organic Cultivation Practice) offers the best compromise solution. The complete order obtained is therefore the following: OCP (Organic Cultivation Practice) > ICP (Integrated Cultivation Practice) > CCP (Conventional Cultivation Practice). The result is obviously much more useful when read in the light of the results related to each single dimension as shown by the impact matrix (table 13). In fact, even though the OCP represents a good compromise between the economic, environmental and social dimensions it is not necessarily evident that the organic system is the best solution when taking into consideration the three dimensions individually.

In the next sections, first the final results in relation to the three dimensions analysed (economic, environmental and social) are presented, then the compromise solution considering simultaneously the three dimensions in terms of final ranking is shown.

Economic dimension result

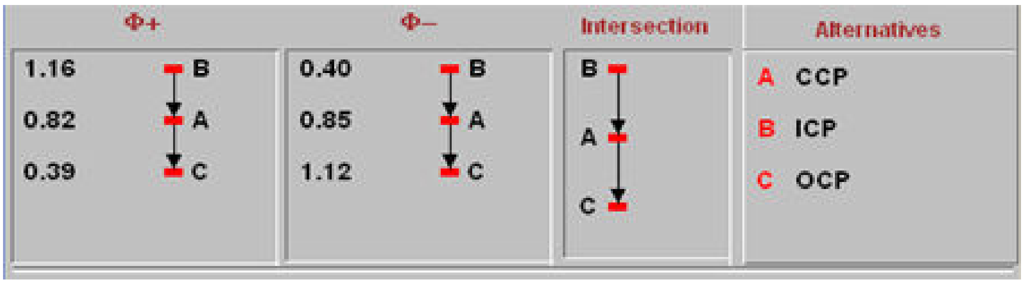


Figure 12 Order of the alternatives according to the economic dimension

Taking into consideration the maximization of the economic efficiency, the alternative that satisfies this goal best is the integrated one (ICP). This alternative thanks to the CAP contributions and thanks to the contributions deriving from the adherence to the agri-environmental enforcement programme (updated by the 2000-2006 Tuscany Region Rural Development Plan (TRRDP), which enforces the EU Regulation 1275/99) showed the highest GSP value and a direct cost value greater with respect to the conventional alternative (CCP) but lower with respect to the organic one (OCP).

The order obtained with NAIADE is therefore the following: ICP (Integrated Cultivation Practice) > CCP (Conventional Cultivation Practice) > OCP (Organic Cultivation Practice), as shown in figure 12.

Ecological dimension result

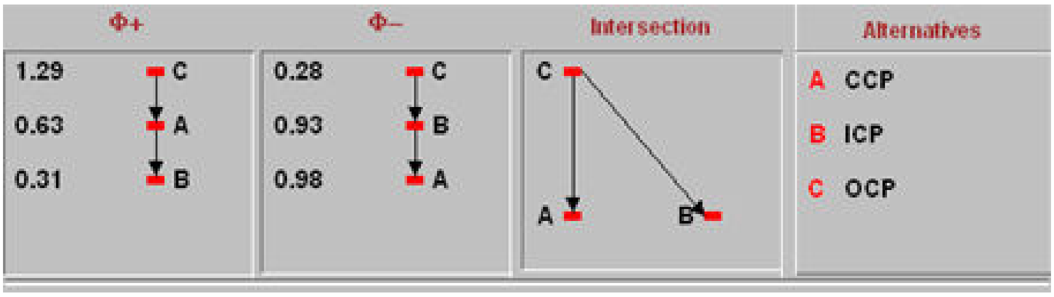


Figure 13 Order of the alternatives according to the ecological dimension

Considering the maximisation of the environmental dimension, the alternative that satisfies this goal best is the organic practice. Although on the surface this appears uninteresting, it is considerably important if one considers how the integrated and conventional systems are placed in the analysis. From the results in figure 13 one can appreciate the incomparability between the conventional system and the integrated one in relation to the environmental dimension. This means that the integrated alternative is not so different from the conventional one with respect to the environmental performances. The order obtained with NAIADE is therefore the following: OCP (Organic Cultivation Practice) > CCP (Conventional Cultivation Practice) and ICP (Integrated Cultivation Practice), as shown in figure 13.

Social dimension result

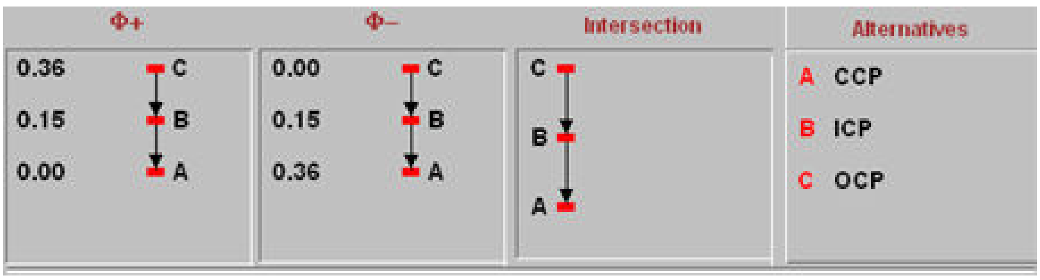


Figure 14 Order of the alternatives according to the social dimension

With regard to the social dimension, the alternative that satisfies the selected indicators best is the organic system. This alternative obtained a very good evaluation in relation to risk of rural area abandonment criterion. Therefore, the order obtained with NAIADE is (figure 14): OCP (Organic Cultivation Practice) > ICP (Integrated Cultivation Practice) > CCP (Conventional Cultivation Practice).

Result integrating the three dimensions

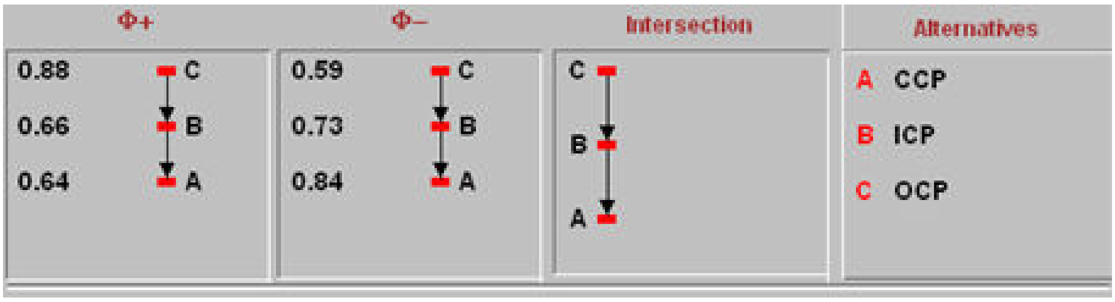


Figure 15 Order of the alternatives according to the maximization of the three dimensions

Taking simultaneously into consideration all the dimensions, it emerges that OCP alternative (Organic Cultivation Practice) offers the best compromise solution. The complete order carried out by NAIADE is therefore the following: OCP (Organic Cultivation Practice) > ICP (Integrated Cultivation Practice) > CCP (Conventional Cultivation Practice). The result obtained is obviously much more useful when read in the light of all the evaluations summarized in the impact matrix (table 13). In fact, even though OCP represents a good compromise between the economic, environmental and social dimension it is not possible to conclude that the organic system is the best solution when taking into consideration the three dimensions individually, as shown by previous analyses (see table 18).

Table 18 Synthesis of the results

Dimensions	**Preferable alternative**
Economic	ICP Integrated Cultivation Practice
Environmental	OCP Organic Cultivation Practice
Social	OCP Organic Cultivation Practice
All the dimensions	OCP Organic Cultivation Practice

In the following sections the evaluations obtained at the moment of the pairwise comparison are presented. These evaluations permit to appreciate the differences in the performances of each alternative with respect to the evaluation criteria.

Conventional Cultivation Practice (CCP) versus Integrated Cultivation Practice (ICP)

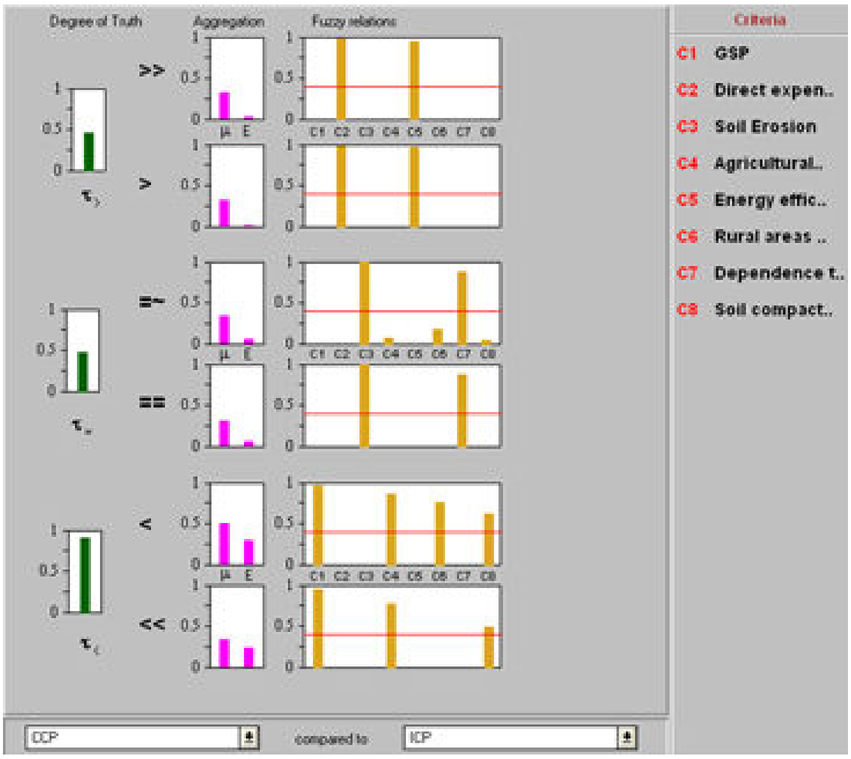


Figure 16 Comparison between conventional and integrated systems

On the basis of the previous evaluations and considering the results as obtained in relation to the evaluation criteria at the moment of the pairwise comparison, the results are as follows:

- The conventional system is able to minimize costs more than the integrated one (C2) and it is more efficient from an energy point of view (C5);
- Conventional and integrated systems are equally dependent on community contributions (C7) and they have the same impact on soil erosion (C3);
- The integrated system is preferable to the conventional one with respect to the GSP criterion (Gross Saleable Production) (C1), the agricultural landscape protection criterion (C4), the risk of rural area abandonment and the soil compacting (C8).

Conventional Cultivation Practice (CCP) versus Organic Cultivation Practice (OCP)

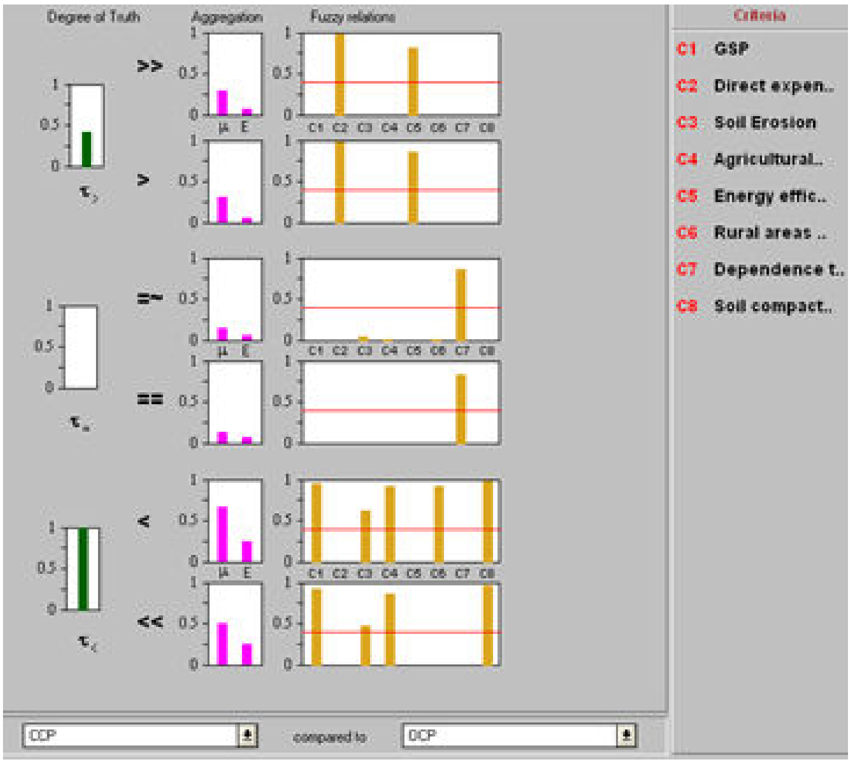


Figure 17 Comparison between conventional and organic systems

As before, the results in relation to the comparison between conventional and organic practices are as follows:

- The conventional system is preferable to the organic one in relation to the direct cost criterion (C2) and the energy efficiency criterion (C5);
- The two systems show the same evaluation in relation to the dependence on community contributions (C7);
- The organic system performs better than the conventional one in relation to the GSP criterion (C1), the soil erosion criterion (C3), the agricultural landscape protection (C4), the risk of rural area abandonment (C6) and the soil compacting (C8).

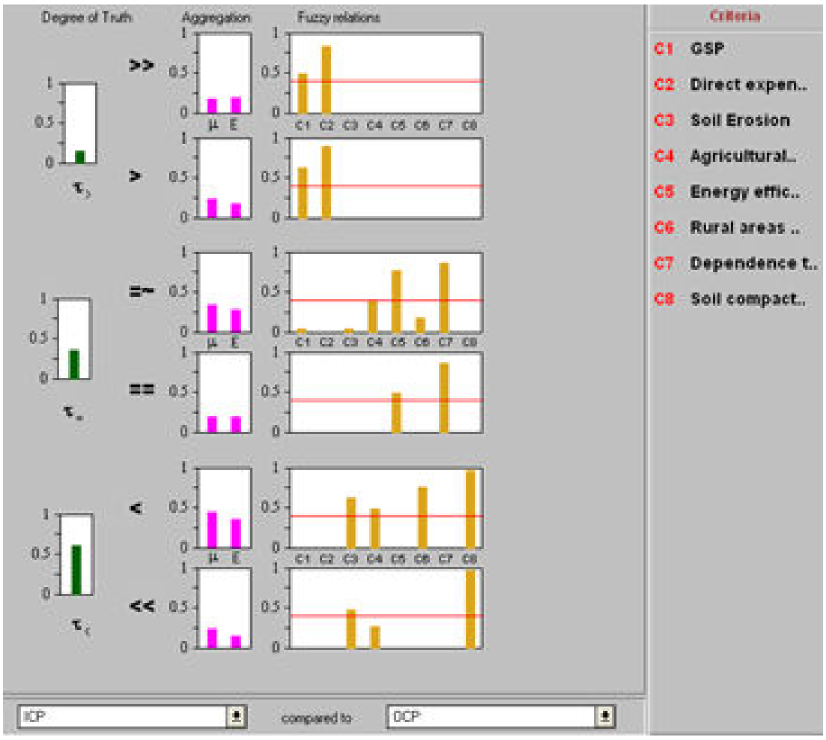


Figure 18 Comparison between integrated and organic systems

Finally, in the comparison between the integrated system and the organic system the results are as follows:

- The integrated system is preferable in relation to the GSP criterion (C1) and direct costs (C2);
- Both systems show the same performance in relation to the energy efficiency (C5) and dependence on community contributions (C7);
- The organic system performs better than the integrated one in relation to the following criterion: agricultural landscape protection (C4), soil erosion (C3), risk of rural area abandonment (C6) and risk of soil compacting (C8).

3.8.5 Sensitivity Analysis

Finally, a sensitivity analysis is performed in order to elucidate conflicts among alternatives and objectives, and to test the robustness of the model (Saltelli et al., 2008). The sensitivity analysis is realized changing the parameters defined by the operator (α and τ parameters), considering also higher and lower crossover values and different operators:

minimum, Zimermann-Zysno and simple product. The crossover values are the points where the preference relation reaches a credibility index of 0.5 (where it begins to be sufficiently credible). The crossover values have been evaluated on the maximum and minimum distance. The results show that the final evaluation is stable and the organic practice is always preferred (see the appendix to chapter 3 for the sensitivity analysis results).

3.9 The effects of the CAP on the soil erosion processes in the study area

Once the relative superiority of the organic farming practice, with respect to the selected criteria is established, it is important to analyse the effectiveness of the EU policies in relation to the diffusion of organic agriculture in the study area, as well as the influence that such policies have had on farmer's decision making and, indirectly, on the erosion phenomena.

Despite the subsidies of the CAP to encourage the practise of organic agriculture, in the study area there are only four organic farming systems. From farmer's questionnaires it emerges that the main reasons for this are principally due to problems of an economic nature and problems with time, also considering that many of the interviewees had only a vague or no idea of what organic agriculture is. These results lead to conclude that, in the study area, the EU policy, which meant to encourage organic agriculture, has had a little effect. One of the main reasons is the poor communication on the methods of soil conservation and on the environmental impacts in the choice of certain agricultural practices on the soil. In fact, neither in the study area, nor at the regional level, specific programs of education exist for farmers on the method of conservation of the soil related to the different possible agricultural practices (i.e. organic, integrated, biodynamic and so on) whilst on the other hand on the environmental impacts on the soil of conventional agricultural practices.

Another key point of analysis is the CAP's influence on the human induced cause of soil erosion in the area. As mentioned, the main anthropogenic cause of soil degradation in the study area is the cultivation of durum wheat without the use of soil conservation rotation plans. From the interviews with farmers it emerged that the choice of cultivating of durum wheat depends on the subsidies received and not on an evaluation based on the future perspectives. As a consequence, the farmers' choice is made without any real interest in the crop and therefore without thinking of the resulting environmental impacts. Thus, two different considerations arise from the previous results. On the institutional side, it can be stated that the EU regulation (CAP) has indirectly influenced the diffusion of the main human induced cause of soil degradation in the study area, driving the farmers, through subsidies, towards the cultivation of conventional durum wheat. On the farmers' side, it can be concluded that the economic dimension is considered most important by those who take the final decision regarding the adoption of one or the other agricultural practice.

The remarks made in relation to the EU policies refer to the old CAP, and it would be interesting to analyse the effects of the new CAP on the farmer choices and therefore on the soil erosion phenomena. The new CAP, thanks to decoupling, grants farmers a greater freedom of choice. The resulting effect could be that of a greater heterogeneity in the choice of cultivation.

3.10 Conclusions

As outlined in the introduction, the main objective of the Tuscany case study is to analyse the economic results and the environmental impact risks of cultivation practices (in relation to the durum wheat cultivation) in the presence of soil degradation. Choosing SMCE as a general framework to analyse specific farms, located in a small rural area within the Albegna river basin in southern Tuscany, in both socio-economic and environmental terms, the following conclusions can be drawn:

(i) the use of the SMCE-methodology has proven to be adequate in evaluating agricultural sustainability of durum wheat cultivation practices in the context of soil erosion;

(ii) organic durum wheat cultivation practices potentially satisfy best a compromise solution considering the economic, environmental and social criteria chosen, in relation to soil degradation processes;

(iii) land use politics (such as the CAP) have a considerable influence on the present management of farming systems and explain to some extent why the present situation does not reflect the outcome of the analysis, which favours organic farming.

The main result of the application of the SMCE, is that the durum wheat organic practice is able to best satisfy the aims of sustainability by reaching a compromise between the protection from erosion and satisfactory economic and social results. This means that even if organic agriculture is not the best solution in relation to each criterion, it offers the best compromise solution simultaneously taking into consideration all the criteria related to the various dimensions considered (economic, environmental and social).

The criteria used in this study are relevant to this particular situation, and have been obtained by the inclusion of the different stakeholders in the selection of the alternatives and the evaluation criteria. Other situations would naturally require the use of other criteria to better assess the different aspects of the same problem.

4 COMBINING MULTI-SCALE AND MULTI-CRITERIA APPROACHES TO ANALYZE URBANIZATION STRATEGIES IN RURAL CHINA

Summary

The present chapter addresses the question of how to best assess the impacts of rural development policies on human and environmental systems across different scales and dimensions of analysis. The study is based upon a combination of multi-scale and multi-criteria approaches (Giampietro, 2003; Munda, 2004 and 2008). This combination allows one to describe the interaction of human societies and ecological systems using simultaneously spatial scale of different levels and looking at different dimensions (social, economic, ecological). The area of study selected for the analysis is that of a rural Chinese island, Chongming. Chongming is currently the poorest district of Shanghai in terms of social and economic development. It has been recently, as of 2005, included in the development plan of the Shanghai municipality, as the key area for the Shanghai's future expansion (The Master Plan of Development of Chongming, 2005-2020). Sustainability in Chongming is a crucial issue, whose successful implementation depends on the capacity of policies to meet socio-economic development while protecting the environment. This chapter examines the economic, environmental and social impacts of future development policies, i.e. rural-urban migration strategies, at two spatial levels: the household and the village. Considerable attention is devoted in the study to the selection of indicators explaining trade-offs between economic development, food security, resource use patterns, as well as environmental protection. Data used for the selection and evaluation of the criteria are of mixed type, qualitative and quantitative and come from: official statistics, in depth interviews and questionnaires with farmers and local people from a rural village in Chongming, agricultural technicians, in depth interviews with individuals in local governments, private institutions, local universities and research institutes.

4.1 Introduction: rapidly changing realities, rural development policies and the need for integrated analyses

The rapid economic growth of China is driving a fast change in the composition of the society and in particular in the structure of the rural areas. One of the results of this change is the rapid urbanization of rural people and, consequently, the impacts in their quality of life (Entwilse and Chen, 2002).

The process of urbanization of rural population represents an increasing phenomenon all over the world. According to the World Bank projections, the level of people living in cities is constantly increasing. Moreover, it has been estimated that almost all of the world's population growth between 2000 and 2030 will be concentrated in urban areas in developing countries (United Nations, 2005) (see chapter 2 for a graph representation of the urbanization phenomenon at the global level).

Among developing countries, China shows one of the highest rates of urbanization. In the last years, rural population has decreased of 13%, ranging from the 73% of the total population in the 90's to 60% in 2005. According to the latest United Nations population projections, by 2030 almost the 60% of the total population will live in urban areas (figure 19).

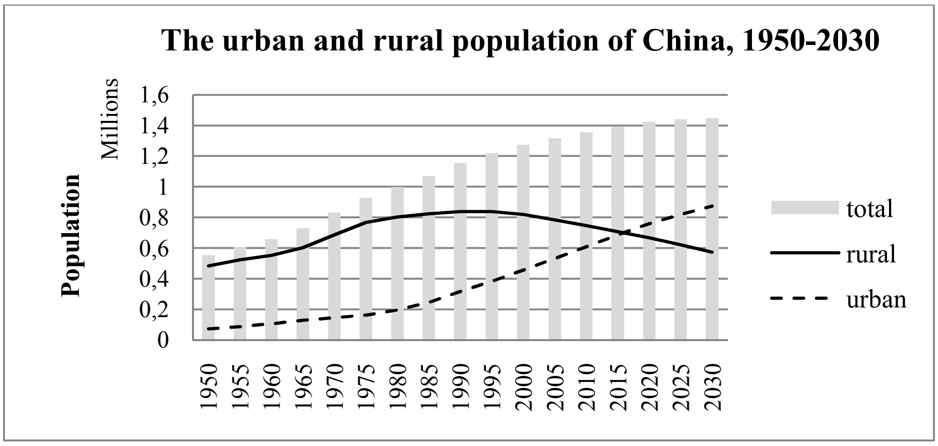


Figure 19 Changes in Chinese rural-urban population from 1950 to 2030.
Source: own elaboration based on United Nations data and projections (United Nations, 2005)

The causes of the rapid process of urbanization of China can be explained considering two different aspects. On one side, urbanization occurs naturally. People move into cities mostly to seek economic opportunities. On the other side, migration is coming to be considered by Chinese policy-makers as a formal "rural development strategy".

As a result, China's modern rural development policy encourages urbanization as one of the main interventions in achieving development goals in rural areas, such as reducing rural-urban gaps in income, poverty and living standards. In regard to that point, the following figure 20 shows, as an example, the income gap between rural and urban households from 1990 to 2006 in Shanghai (comprising all the 18 county-level divisions: Shanghai proper, inner suburbs, outer suburbs and the islands). As we can see, the gap is constantly increasing and the growth rate of urban households' income is almost twice that of rural households (8.5 versus 4.5, respectively).

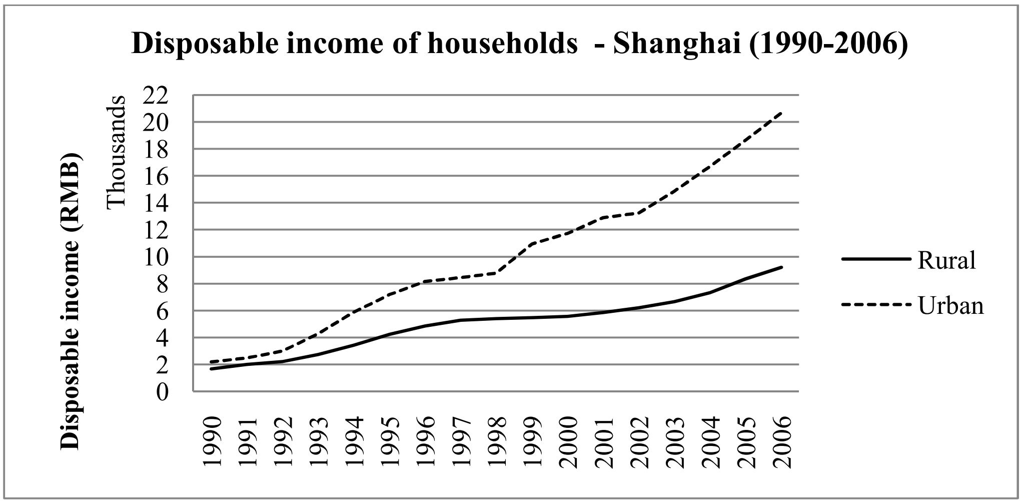


Figure 20 Disposable incomes of rural and urban households in Shanghai from 1990 to 2006. **Source:** own elaboration based on data from Shanghai Statistical Bureau (Shanghai Statistical Yearbook, 2007)

The magnitude and the rapidity characterizing the urbanization process all over the world, and especially in developing countries, have called the attention of the scientific community. At present, a growing number of studies have examined the impacts of urbanization processes on social and ecological systems, especially in China. They are mainly focused on two aspects: (1) the analysis of the socio-economic and environmental impacts of fast urbanization processes in urban areas (Lei Shen et al., 2005; Ren et al., 2003; Jie Chen, 2007; Roy, 2009; Henderson et al., 2007; Vernon, 2009); and (2) the environmental consequences of urbanization related land use changes due to the spatial expansion of cities occupying new territories (Vickery et al., 2009; Antrop, 2004; Deng et al., 2009). Furthermore, they often refer only to one scale (mainly global, national or regional) or one dimension of analysis (mostly economic or environmental).

Rural areas near the big cities are particularly affected by the presence of rapidly changing circumstances. This is also the case of Chongming island, which, due to its position, is predominantly influenced by the rapid development of the city of Shanghai. In particular, Chongming has been recently included (as of 2005) in the development plan of the Shanghai municipality, as the key area for Shanghai's future expansion (The Master Plan of Development of Chongming, 2005-2020). The main objective of the overall plan is the socio-economic development of the Yangtze Delta.

Interventions are mainly driven by a complete reorganization of the island in terms of land uses, and rural areas will be the most affected by this change. The urban area will increase and as a consequence agricultural areas will be reorganized based on the concentration of rural people in rural residential zones and new rural villages. This change will be linked to a reduction of the total rural population.

The main aims of the future development plan of the island are the following:

- To increase the economic development and the income level of the Chongming population, through an increase of the urban population;
- To improve the environmental quality of Chongming, especially related to the soil resource;

For local governments and institutions, sustainability in Chongming is a crucial issue in terms of the capacity of development policies to meet socio-economic development while protecting the environment. Several studies have already explored the issue of sustainability in the island. They are related mainly to the development of sustainability indicators and indexes applied to the entire island level (Shi et al., 2004; Yuan et al., 2003), and to the importance of the island from an environmental point of view (Zhao et al., 2003; Xiaobo et al., 2008; Tian et al., 2008; Huang et al., 2008). The goal of this research is to introduce the concepts of sustainability in a multi-scale perspective taking furthermore into consideration the socio-economic dimension. Previous studies realized in Laos, China and Vietnam (Grünbühel and Schandl, 2005; Pastore et al., 1999; Gomiero et al., 2001 respectively) demonstrate the potential of multi-scale and multidimensional approaches to analyze the impacts of development policies on rural areas, linking land use, income generation, material consumption, and showing physical constraints of further economic development.

Based on the above considerations, I utilized both multi-scale and multi-criteria approaches (Giampietro, 2003 and Munda, 2004 respectively) as a way of understanding the impacts and coherence of Chongming rural-urban migration policies across scale taking into account two levels of analysis: the rural household and the village.

Results allowed to better understand the biophysical and socio-economic structure of rural households/communities in Chongming and at the same time to analyze trade-offs between different multidimensional objectives, such as the economic, environmental and social dimensions at the household and village levels. For rural households, sustainability has both biophysical and socioeconomic elements, and one element cannot be sustainable without the other (Eckman, 1994). It is for this reason that even well-planned development policies and programs sometimes have negative impacts if they don't take into consideration the relevance of decisions taken at the level of rural households.

The choice of the households and village as the units of analysis is also due to the fact that in Chongming island they represent the most significant organization at the geographical and social points of view.

This chapter, after presenting the methodological aspects of the MuSIASEM approach and the integrated approach used based on the combination of multi-scale and multi-criteria approaches (sections 4.2 and 4.3), provides some information regarding the socioeconomic and environmental characteristics of the area under investigation (section 4.4), and elucidates the strategies and measures of the Chongming development policies (section 4.5). After that, first section 4.6 presents the different scenarios analyzed and then section 4.7 explains the use of the multi-variate statistical methods for the creation of rural households' typologies that are representative of the social structure of the rural village under investigation, Hongxing village. The typification of rural households is used to subsequently compare the village and households' performance by means of multidimensional indicators reflecting the following variables: human time, land use, energy and food consumption and income generation. In sections from 4.8 to 4.16 the final results are presented and discussed in the light of the potential trade-offs rural households and Hongxing village have to face in decision making with regard to income generation, environmental protection, food security, risk diversification and quality of life. Finally, in sections 4.17 and 4.18 a more general discussion of the results obtained together with concluding remarks is provided.

4.2 The integrated framework of the research

The integrated framework applied in this case study has been based on the combination of MuSIASEM and SMCE (see chapter 2). The two models can be considered having a common framework based on a process of learning that allows integrating qualitative and quantitative analyses for a better understanding of both the problem and the area under investigation. A learning process combines the exchange of the social actors' knowledge with that of experts to provide new conceptual frameworks and to enable reflection, feedback, decision and action planning. In the MuSIASEM approach the social actors' knowledge is used for the variables' specification and parameterization through a process of data collection (during the investigation phase). In the SMCE, the social actors' participation is used all the way through the steps of the analysis, including also the evaluation phase.

Within the SMCE and MuSIASEM frameworks, the analyses performed in this particular case study are the following:

1) Historical and institutional analysis;
2) Definition of the development scenarios according to the main development policies interventions;
3) Definition of the levels and variables of analysis;
4) Definition of the typologies of rural households and their distribution;
5) Construction of the multi-level matrices using the multi-scale approach;
6) Identification of the evaluation criteria based on the objectives of the RDP;
7) Attribution of the evaluation criteria scores;
8) Construction of the impact matrices for each scenario of development;
9) Analysis of the results and trade-offs.

The framework applied is composed by two main parts (see figure 21). The first one refers to the investigation phase in which the steps from 1 to 6 are realized to characterize the area under investigation. It involves looking at the historical and current situation of the area based on the study of the literature, the collection of data (combining the social actors' knowledge with that of experts), the analysis of the local, regional and national policies associated with the site. All the information is then collated to make a characterization of the area under investigation from a socio-economic and environmental point of view, to construct the scenarios and finally to select the evaluation criteria. This phase includes also a preliminary elaboration of the data collected (steps 4 and 5).

The second phase is the evaluation phase, in which the data collected are elaborated to evaluate the scenarios, and the outcomes of the study are analyzed (steps from 7 to 9).

The two methodologies, SMCE and MuSASEM, are used separately in the realization of the investigation phase (from 1 to 6) and then integrated for the evaluation phase (steps from 7 to 9).

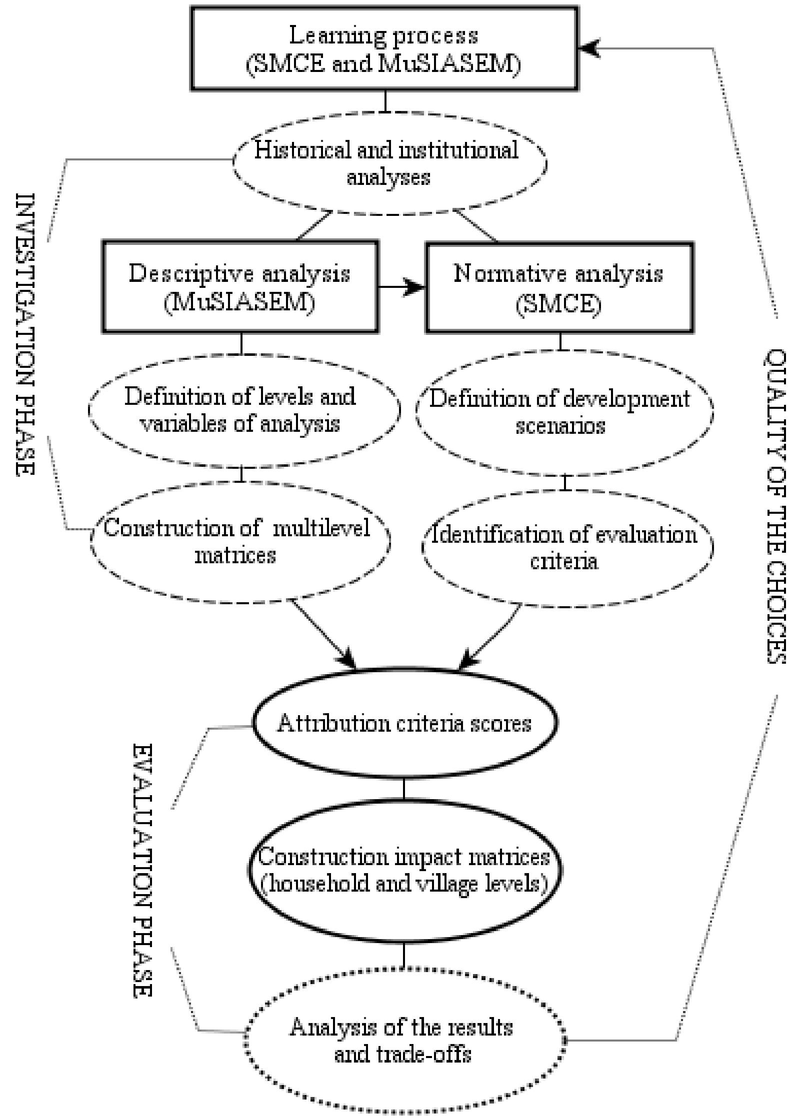


Figure 21 The integrated approach used, based on the combination of SMCE and MuSIASEM

The SMCE has been used for the definition of the development scenarios and of the evaluation criteria based on the analysis of the rural development policies goals and interventions across scales (national, regional and local). Moreover, the construction of the impact matrices for each scenario follows the rational of the MCDA based on the integrated representation of the alternatives by means of the use of multidimensional criteria. Therefore, just some of the steps that characterize a SMCE framework have been applied. In particular, the participatory process and the application of the aggregation procedure to construct the final ranking of the alternative scenarios, have been avoided (see chapter 2 for a detailed description of the steps that characterize a SMCE). Since the final aim of the research has been to examine alternative scenarios from a multidimensional perspective rather than to perform a conflict analysis, the participatory process has been realized for the collection of data and for the parameterization and calibration of the variables. As a consequence, social actors have been only involved in the analysis with the purpose to collect technical information related to the final evaluation of the criteria. Moreover, since the aim of the research is the analysis of impacts and trade-offs among various criteria rather than providing one optimal solution, the application of the aggregation procedure hasn't been applied.

Concurrently, the multi-scale integrated analysis has been used for the evaluation of the criteria across scales and for the parallel representation of the “socio-economic” and “environmental” dimensions of the area under investigation.

As it has been pointed out above, the main levels of analysis chosen for this research have been two: the household and village levels. While, the main variables used for the representation of the levels of analysis have been four: human time, land use, gross income and energy consumption. These variables are able to represent simultaneously the “socio-economic” and the “environmental” dimensions of the levels under investigation. At the same time, their quantitative representation across scales gives us the basic information for the calculation of the criteria scores useful for the construction of the impact matrices. The impact matrices are used for the analysis, in a multi-criteria performance space, of the different scenarios of development at the village and household levels. The definition of the development scenarios is related to the main interventions of the rural development policies at the village level. While, the definition of the evaluation criteria refers to the development goals across scales (see table 20). In other words, the scenarios analyzed represent what is more likely to take place in the future, as inferred from the changes that recently took place in the site and the RDP goals.

The integrated framework proposed has been applied to the analysis of the impacts of development scenarios at the local level for three main reasons. First of all, the issues involved different scales and levels of analysis. Development policies goals in Chongming island are designed at different levels, i.e. national, regional and local (see section 4.5) and the resulting interventions have impacts at different levels, i.e. individual, household, community, town, the entire island.

Secondly, the impacts refer to different dimensions of analysis, i.e. the economic, environmental and social dimensions. Thirdly, rural systems are complex systems characterized by the interactions with the external socio-economic and environmental contexts. Therefore, they need to be analyzed by an integrated methodology that allows taking into account different assessment criteria which refer to a wide range of scales and dimensions.

Based on the above considerations, SMCE allows for the analysis of the scenarios using simultaneously different criteria and also quantitative and qualitative evaluations. Qualitative evaluations in particular are essentials for the analysis of the social impacts of RDP interventions. Concurrently, the multi-scale integrated analysis permits the evaluation of the criteria across scales and a representation of the complexity of the system under investigation. This is achieved by means of fund and flow variables illustrating the various interactions between the system and the external socio-economic and environmental contexts. The analysis builds upon the previous identification of household typologies representative of the social structure of Hongxing village, as it is explained in section 4.7.

4.3 The multi-scale approach: methodological aspects

This section presents the methodological aspects of the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) approach developed by Mario Giampietro (Giampietro, 2003 and Giampietro et al., 2008) (some general information about the approach are also provided in chapter 2).

The MuSIASEM approach assumes that a particular social system (a country, a village, a rural or urban household, an individual), can be described by applying in parallel an "economic reading" and a "biophysical reading" through the integration of the following concepts and methods:

1) the concepts of societal and ecosystem metabolism and of "endosomatic" and "exosomatic" metabolism;
2) the fund-flow model;
3) the concepts of extensive and intensive variables;
4) the multilevel matrices method to establish a link across levels;

In biophysical terms, a metabolism of a particular system can be described taking into consideration the principles of “endosomatic” and “exosomatic” metabolism (Georgescu-Roegen, 1975). An endosomatic metabolism refers to all the energy and material flows metabolized by the human body to sustain its activities, such as food energy. While an exosomatic metabolism refers to all the energy and material flows metabolized outside the human body to have an additional support in terms of efficiency and power for the realization of various activities (for example the use of tractors for the production of food). All these fundamental elements for the functioning of the system come from its continuous interaction with the external environment “exchanging flows of energy, matter and gross income” (Giampietro, 2003). These interactions can be represented by the use of a fund-flow model (Giampietro et al., 2008, from Georgescu-Roegen, 1975). At the same time flows and funds can be represented by adopting a method of accounting based on the use of multi-level matrices and the concepts of extensive and intensive variables to establish a link across levels and scales.

4.3.1 The interactions between meta-agents: the fund-flow model

According to the fund-flow model proposed by Georgescu-Roegen, when studying a CAS in terms of both the interaction of the system with its external context and the description of its main characteristics, two different categories of elements have to be considered: flow and fund categories (Georgescu-Roegen, 1975). Flow categories are “elements that enter but do not leave the process, or conversely, elements that exit without having entered the process”, such as for example energy, matter, money, information, while funds refer to “elements that enter and exit the process unchanged” (Mayumi, 1999), such as human time, land or the number of people. In other words, funds and flows are all the variables and factors that describe the interaction among the system and the economic and environmental contexts embedding the system itself (i.e. among the meta-agents composing the hierarchical organization of the system). By adopting this approach CAS can be represented as metabolic systems organized on nested hierarchical levels characterized by the exchange of inputs (e.g. energy, food, money, information), i.e. the flow elements, and by a given structure represented by fund elements (e.g. the size of the system expressed by time, land, people, capital).

4.3.2 Multilevel matrices to establish a link across different hierarchical levels

According to the MuSIASEM approach, the hierarchical organization of CAS can be represented by a combination of the concepts of intensive and extensive variables and multi level matrices method.

Concepts of extensive and intensive variables come from thermodynamics[27], in which extensive variables are those that vary linearly with the size of the system, while intensive variables are independent of the size. In the MuSIASEM approach, extensive variables refer to fund and flow elements, while intensive variables are obtained by the ratio between flows and funds. An example of extensive variable could be that of the fund "human activity" expressed in hours, which changes when for instance the size of the system in terms of number of people varies, while an intensive variable could be that of the flow of money per hours of work (flow/fund). In other words, intensive variables represent synthesized information, i.e. multidimensional indicators of the performance of the system ("what the system does" in terms of the interaction with the external contexts); while, extensive variables describe the state of the system ("what the system is" at a certain moment in space). A crucial aspect of fund and flow elements and therefore extensive variables is that they can be represented by the use of multilevel matrices, which is a way to bridge representations within scales. A multilevel matrix is characterized by congruent relations among the elements pertaining at different hierarchical levels. For example when considering the fund "human activity", the Total Human Activity (given by the population size and the amount of hours available in a year) at the level of a country (level n), must be equal to the sum of the hours of human activity considering two sectors (level n-1): hours of human activity in "paid work" and hours of human activity in "non paid work" (e.g. education, leisure, subsistence, sleeping, personal care). Then it is possible to scaling down to lower hierarchical levels, where the total human activity of the sub-sector "paid work" must be equal to the sum of the human activity in the sub-sub sectors (level n-2) expressed for example by the economic sectors: agriculture, industry, trade and services. At the same time, the latter can be expressed by the sum of the hours of human activity dedicated to the different sectors by the households or individuals

[27] Examples of extensive variables in thermodynamics are: volume, mole, entropy, internal energy. While, intensive variables commonly encountered in thermodynamics are: temperature and pressure.

composing the starting level n. The same rational can be applied to different funds and flows, such as energy, money and land.

An example of multilevel matrices for the representation of the fund "human activity" and the flow "gross income" is given in figure 22. The categories used here for the construction of the multilevel matrix are the following[28]:

- Total human activity (THA), which represents the total disposable hours of the population in a year (8760 hours per capita in a year x total population). This amount is composed by the hours people dedicate to working activities in the paid work sector (HApw, human activity paid work) and the hours dedicated to activities in the non paid work sector (HAnopw, human activity non paid work).
- The "paid work" sector and "non paid work" sector are composed respectively by the hours in the economic sectors, agriculture (HAagr), industry (HAind) and trade and services (HAt&s) and by the hours dedicated to non paid activities, such as household chores (HA hc), leisure and education (HAl&e), physiological overhead (HApo) and for subsistence purposes (HAsub).

The same categories have been used for the representation of themonetary flow, expressed by the Gross Income (GI) variable. In this case the "non paid work" sector has been estimated based on the monetary value of the human activity dedicated to subsistence purposes (i.e. the "virtual income" calculated based on the self production of food, for more details on the estimation procedure see paragraph 4.11.1).

The matches between flows and funds give intensive variables, in other words benchmark values for the metabolic characterization of the system under investigation.

The multi-level matrix shows a parallel representation of the fund "human activity" and the monetary flow expressed by the "gross income" over a set of meta-agents (simplified and aggregated representation of the system under investigation) represented by the different levels of analysis (i.e. HApw, HAno pw, HAind and so on).

Level n represents the higher level (e.g. a country, a village, a town); level n-1 represents the production and consumption sectors ("paid work" and "non paid work" sectors); level (n-2) the sub sectors (e.g. agriculture, industry, trade and services) composing the sectors of the higher level (n-1); and finally level (n-3) represents the various household types that contribute with their decisions to the formation of the fund "human activity" and the flow

[28] As we can appreciate from the explication of the structure of a multilevel matrix, we are applying here the same concepts described in paragraph 1.1 regarding the structure of CAS based on the presence of meta-agents (Holland, 1995), which in this case corresponds with the definition of different functional categories (i.e. paid work and non paid work sectors, households, village and so on).

"gross income" (it is at the household level that individuals decide how to split their available time into different paid and non paid working activities which in turn have an influence on the formation of the available income).

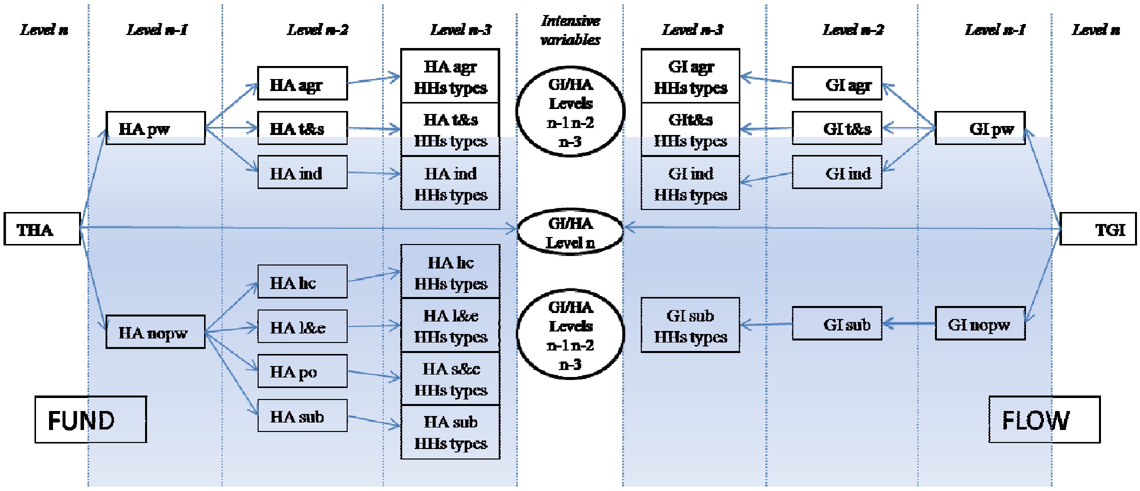


Figure 22 Multi-level matrix of the fund human activity against the monetary flow

All the meta-agents represented in figure 22 are described by information obtained through a process of aggregation of the information at the lower levels. The ratios between flow and fund elements represent intensive variables (e.g. the gross income per hour of human activity). Intensive variables can be used as benchmarks to provide a qualitative and quantitative characterization of the system under investigation and/or multidimensional indicators to describe the performances of the system across scales.

Summarizing, the multi level matrix has the prerogative to characterize a given profile of distribution of a given fund and a given flow across levels. This characterization makes it possible to establish a set of relations of congruence between the value taken by intensive and extensive variables across levels (Giampietro, 2008).

The following equation is an example of the relation of congruence across levels that characterize a multi-level matrix, considering also the intensive variable represented by the flow gross income over the fund human activity at level n.

$$\frac{TGI_n}{THA_n} = \frac{\sum_{i=1}^{P} GI_{(n-1)i}}{\sum_{i=1}^{NP} HA_{(n-1)i}} = \frac{\sum_{i=1}^{S} GI_{(n-2)i}}{\sum_{i=1}^{S} HA_{(n-2)i}} = \frac{\sum_{i=1}^{H} GI_{(n-3)i}}{\sum_{i=1}^{H} HA_{(n-3)i}} \qquad (1)$$

Where GI is the gross income; HA is the human activity; P and NP represents the paid work and non paid work sectors; S represents the various economic sectors (agriculture, industry, trade and services) finally H represents the total number of households.

4.4 Chongming island and Hongxing village: socioeconomic and environmental background

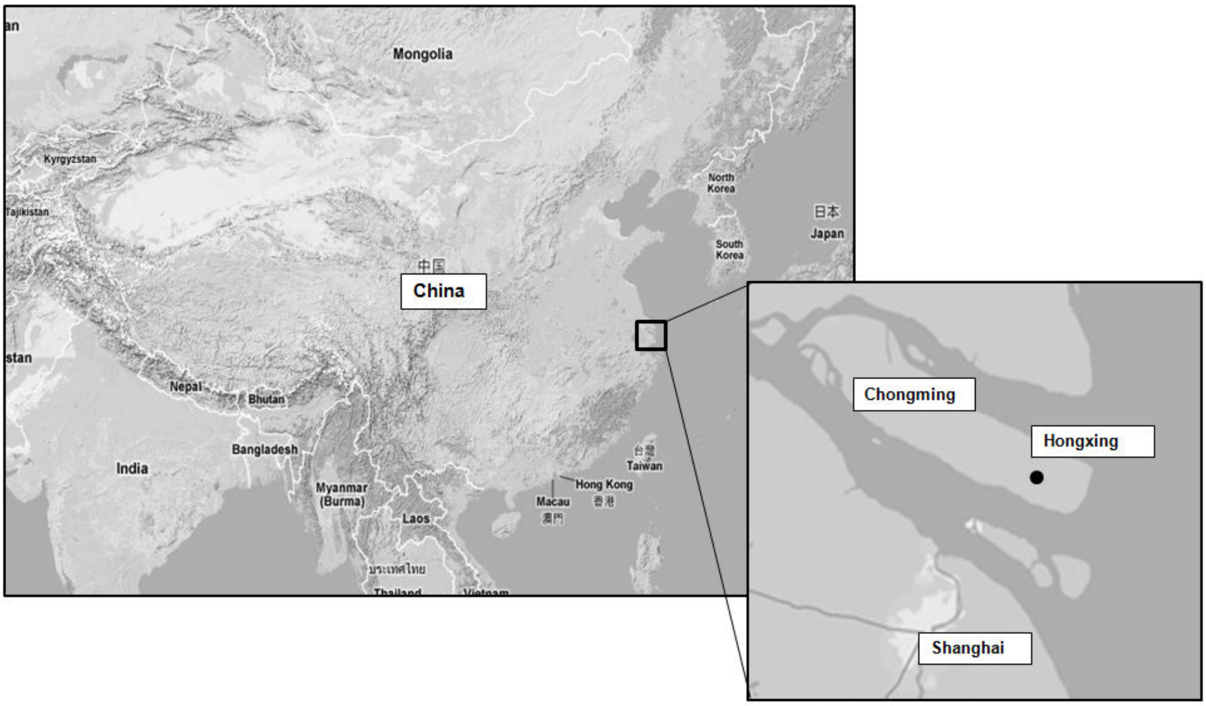


Figure 23 Chongming island and approximate location of Hongxing village (*Source*: Google Earth)

Chongming, with an area of 1,411 km^2 and a total population of 697,101 inhabitants (Statistical Yearbook, 2007), is the third largest island in China (figure 23). It is the largest alluvial island situated in the Yangtze Estuary and is administrated by Shanghai's Municipal Government.

By World War II a considerable population living by fishing and cultivation settled on the island. After 1949 an effort was made to restore the island to productivity. Beginning in 1959–60, extensive recuperations of mudflats areas were made, and a large area was provided with irrigation and drainage ditches. Due to the excessive salinity of the island, the land was first planted with cotton, which is highly resistant to alkaline conditions. After cotton had been grown for several years, the land was used for grain cultivation and for fruits, vegetables, and poultry for the urban market of nearby Shanghai (Chongming, 2009).

Nowadays, the economic structure of Chongming is dominated by the agricultural sector which led the economy of the island with more than 50% of the total gross income produced in 2007. In the agricultural sector plantation, livestock and aquaculture activities contribute to the production of the main fraction of gross agricultural output value (table 19).

Table 19 Agricultural gross output value Chongming island, 2007

Activities	Gross output value (absolute value-billion RMB)	%
Plantation	2.22	49.13
Forestry	0.11	3.81
Livestock	0.57	19.72
Agricultural service	0.09	3.11
Fishery-aquaculture	1.05	22.49
Total	**4.49**	

Source: Statistical Yearbook, 2007

The rural population constitutes a high percentage of the total population, 72% c.a., with a total number of rural households of 289,500, while rural villages account for 223 (Statistical Yearbook, 2007). The land used for agriculture amount for the 82% of the total land and only 4% is covered by forests (see figure 24).

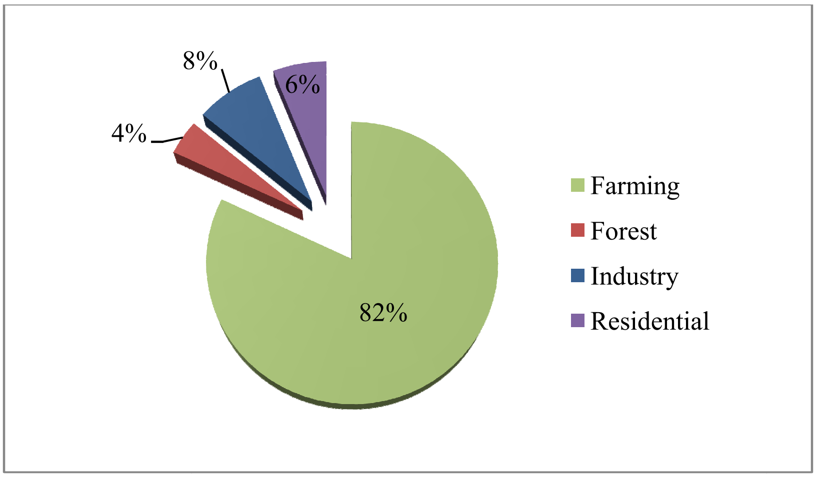


Figure 24 Land use in Chongming island - 2007

The industrial sector is mainly based on the production of universal equipments, metal products, traffic and transportation vehicles and construction. Large-scale industrial enterprises dominate the industrial sector of the whole county. However, the total population living merely on industry is very low, underlining the traditional agricultural profile of the island. According to the official statistics (Statistical Yearbook, 2007), urban people reaches only a 28% of the total population and are concentrated in 16 towns.
The island is in general not affected by industrialization in terms of environmental degradation. It is considered the last “spotless land” in East China. However, the high population density has put great pressure on the natural and economic resources, in particular by the use of a massive amount of fertilizers and pesticides in the agricultural production. A study realized by the Centre of Competence for the Innovation in the agro-environmental sector (Agroinnova) of the University of Turin, in collaboration with the Shanghai Academy of Environmental Sciences (SAES), reveals for conventional corn cultivations in Chongming the use of 401.7 kg/ha of fertilizers (far over the national safety limit of 225 kg/ha) and 1,740 g/ha of chemical pesticides (Sino-Italian Cooperation Project, 2008). One of the main consequences of the massive use of fertilizers is the process of salinization of the soil which, in most of the cases, represents the main environmental degradation in the island.
Population is composed for the majority, 65% c.a., by people in the age class between 18 and 59 (figure 25).

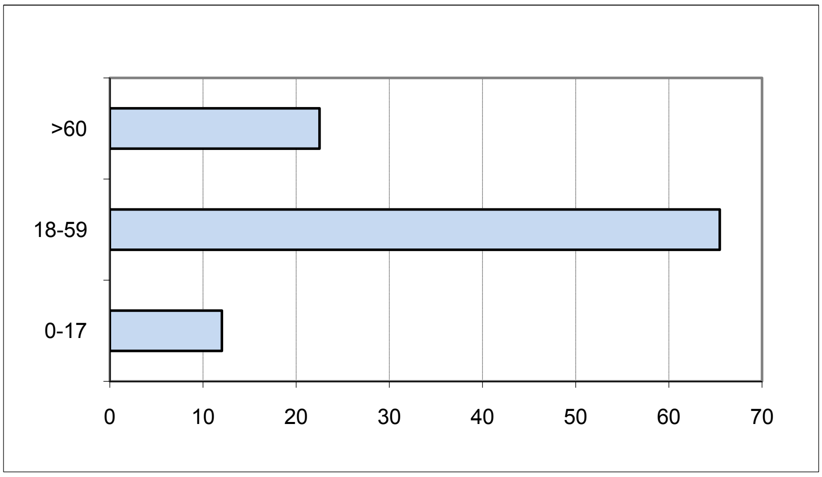


Figure 25 Population per age classes Chongming island - 2007

Chongming is currently the poorest district of Shanghai in terms of social and economic development. According to the Statistical Bureau of the Shanghai Municipality (Statistical

Yearbook, 2007) the average net income per capita of the rural population in Chongming is just slightly over the lower income economies threshold of the World Bank (1095 US$/year vs. 936 US$/year), and very low in comparison to the average income per capita of the urban population in Shanghai (2730 US$/year).

4.4.1 Geological environment and natural resources

Chongming island terrain is flat, there are no hills or mountains, but the terrain is higher in the northwest and central parts and slightly lower in the southwest and east. In the south-east part of the island there is an important wetland, it is the only high quality natural resources currently existent in Shanghai. In February, 2002, Dongtan Wetland has been officially included in the world important wetland list by Ramsar Convention on Wetlands. It is one of the largest protection zones for migratory birds in East Asia (SIIC, 2003). The vegetation of the island has been greatly modified by the human activity. As a consequence, the native forest covers just a little area of the entire island (Huang et al., 2008). As a result agroecosystems dominate most of the land use and provide most of the food supply.

Hongxing village: some basic information

Hongxing village is located in east Chongming (figure 23) and it is under the administration of Zhongxing town. Zhongxing town has an administrative area of 45.54 km^2 and a population of 30,819, including a rural population of 27,149. The town administers over 12 rural villages. The agricultural sector is specialized in the production of cauliflower, vegetables and crabs, which unlike of rice, wheat and corn (typical cultivations in Chongming) allow farmers to reach higher economic returns. Hongxing has a population of 2,683 inhabitants (on average 2,5 people per household, as a consequence of the birth planning program, i.e. one child per couple birth limitation policy promoted in 1979 by the central government). The majority of the economically active population is engaged in agricultural activities for both subsistence and commercial purposes.
Next figure shows the different land uses in Hongxing village.

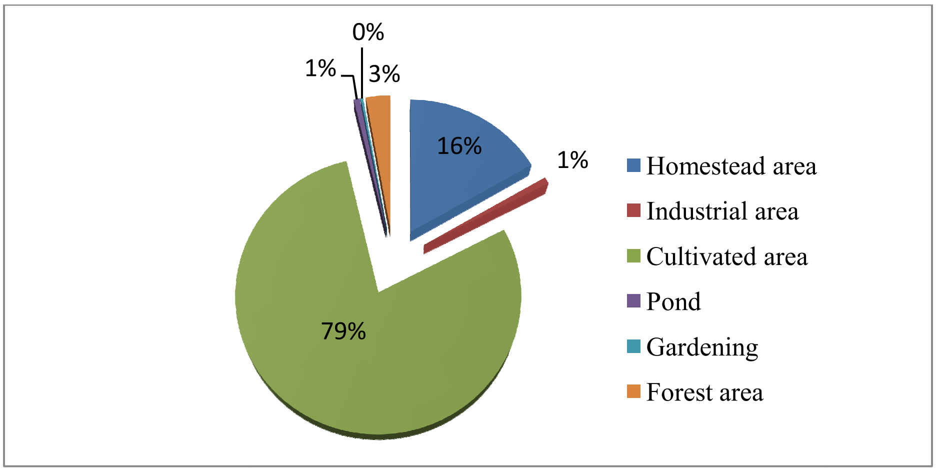


Figure 26 Land use in Hongxing village

Main cultivations are: fruits, vegetables, corn, rice and wheat. Among them, vegetables and in particular cauliflowers prevail in terms of number of hectares. Vegetables, fruits and corn represent the most productive cultivations in terms of income generation; wheat and paddy are primarily subsistence crops. In particular, based on information collected on the field during an interview to the head of the village, the 98% of the paddy is cultivated for subsistence, wheat 52%, vegetables 19%, corn 10%, fruits 3%. Livestock activity is also performed mainly for subsistence; only a small number of households raise animals for commercial purposes. Aquaculture is realized in a small scale and the production of crabs is the most relevant.

From a demographic point of view, the population in Hongxing is, for the most part, made up by elderly of 65 and over.

4.5 Chongming development policies

One of the main projects undertaken recently by Shanghai's Municipal Government is the Chongming Island development. The government of Shanghai has developed a comprehensive master plan for the achievement of a sustainable development of the island by the year 2020.

The master plan refers to the guidelines of the 11th Five-year Plan for Chongming National Economic and Social Development approved in the 4th Session of the 13th National People's Congress of China (NPC) (The Master Plan of Development of Chongming, 2005-2020) (State Council of China, 2004).

The master plan, addresses the following distinct objectives:

- Increasing the income per capita of the rural population;
- Putting into force the development strategy based on the “rural-urban migration”;
- Introducing the production of organic agriculture in the southern east area;
- Reducing the level of pollution especially on soil;
- Increasing the investment in education;
- Promoting the diffusion of agricultural areas for large scale food production.

Next table shows a summary of the different development policies objectives across the scale: from the national to the local level. The definition of the policy objectives usually follows a top-down approach. At the national level there is the definition of general objectives, and then they become more specifics across scales followed also by a definition of the interventions to be implemented at the local level. Interventions are in general supposed to satisfy the main goals defined at the broader levels.

Table 20 Development policies goals across scales: from the national to the local level

Scales	Main goals	Main policy interventions
National ***China Government*** ***11th Five-Year Plan***	- Food security - Environment protection - Economic development - Good management of natural resources	To be defined at the lower levels…
Regional ***Shanghai Municipality*** ***11th Five-Year Plan***	- Economic development - Environmental quality - To increase the tourist sector	- Increase the urban population - Introducing eco-agriculture - Increasing the forest area
Local ***Chongming Master plan***	- Increasing the income per capita - Reducing pollution especially on soil - Promoting large scale food production - Increasing education	- Putting into force the “rural-urban migration ” strategy - Introducing eco-agriculture - Increasing urbanization

Source: The Master Plan of Development of Chongming, 2005-2020, 11th Five-Year Plan of Shanghai Municipality, 11th Five-Year Plan for National Economy and Social Development of China

The main interventions of the Master plan at the local level, is the application of the rural-urban migration strategy, which is the gradually process of urbanization of rural households and villages. This process is linked to the realization of agricultural areas in the same land where currently rural villages are located. According to the master plan, the process of urbanization of rural people linked to the creation of agricultural and eco-agricultural areas will permit the achievement of the development goals listed in table 20. The coexistence of big agricultural areas and rural villages is already a reality in Chongming. Shanghai Industrial Investment Corporation (SIIC), the largest international investment group company owned by Shanghai Municipal Government is responsible for the management of a big agricultural area called Dongtan, located in southern east Chongming (see figure 27). This area represents one of the biggest agricultural areas in Chongming and one of the most important food supplies for the city of Shanghai.

Figure 27 Southern Chongming island, SIIC Dongtan agricultural area
- (*Source:* Google Earth)

4.6 Definition of the development scenarios

Hongxing village, located in the southern east part of Chongming will be affected by the development plan through the realization of the following two main interventions:

- the diffusion of agricultural areas based on large scale cultivations (eventually performing organic agricultural practices) and industrial agriculture (i.e. high external power agriculture -HEPA);

- the “rural-urban migration” strategy related to the gradually integration of the existing rural villages into new denser cities located along the cost.

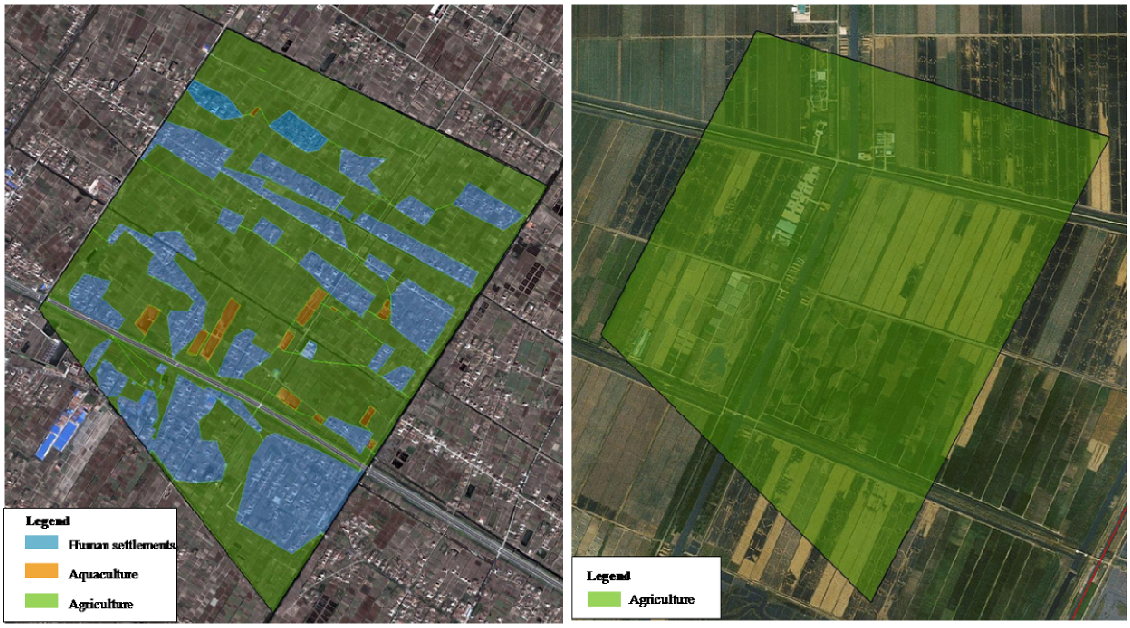
In other words, the idea behind the “rural-urban migration” strategy is to completely shift the use of the land of Hongxing village to only agricultural land, characterized by the realization of large scale food production (industrial agriculture or HEPA). Moreover, as a consequence of the forced migration to cities, the work patterns of people will change from those at present, which are based on a diversification of the working activities (off-farm, on-farm and partially off-farm household typologies) to off-farm patterns only (for the method used to classify the household typologies in Hongxing village see section 4.7).

Based on the above mentioned interventions, the identified scenarios are:

1) “Business-as-usual scenario” (i.e. Hongxing village). This scenario supposes that the current land use management does not change over time. The test area is characterized by different land uses, such as human settlements and the agro-ecosystem, and on low external power agriculture (LEPA) (i.e. the traditional agriculture paradigm)[29];
2) “Conventional agriculture scenario”. This scenario supposes that the land use shifts to only agricultural land. The test area is then characterized by one land use, the agro-ecosystem, and by high external power agriculture (HEPA) (i.e. the industrial agriculture paradigm).
3) “Eco-agriculture scenario”. This scenario has the main characteristics of the previous one in terms of land use, only agricultural land, but it differs for the introduction of organic agriculture techniques (i.e. industrial paradigm but with a reduction of fertilization).

The scenarios relate to different patterns of land use (multi-functional versus mono-functional land uses), as well as to different agricultural paradigms (traditional versus industrial agricultural methods). Figure 28 shows the scenarios based on the land use change due to the implementation of the rural-urban migration policy in Hongxing village.

[29] For traditional or low external power agriculture (LEPA) we consider here a type of agriculture in which no machines are employed. On the contrary, industrial or high external power agriculture (HEPA) is based on the extensive use of tractors. Another definition that applies in this case is that HEPA is a type of agriculture which is strongly market oriented, tends to be capital-intensive and highly mechanized, consuming large quantity of non-renewable resources (such as fossil fuels). On the contrary, LEPA is realized prevalently for subsistence purposes, it is based on manual work instead of the use of machines. Therefore, it results less capital-intensive than HEPA.



BAU scenario – Hongxing village characterized by local communities, the village and the agro-ecosystem

Scenarios 2 and 3– Agricultural area characterized by the agro-ecosystem only

Figure 28 Representation of the scenarios according to different land uses. (*Source: Google Earth)*

Table 21 Overview of the alternative land-use scenarios

Scenarios	Main characteristics
BAU scenario **Hongxing village**	• **Multi-functional land uses**: human settlements (local communities), aquaculture, and agriculture (agro-ecosystems) • **LEPA - Low External Power Agriculture**: low capital-intensive, weakly market oriented (mostly subsistence agriculture), no mechanized, consuming small quantity of non-renewable resources (such as fossil fuels) • **Conventional agricultural methods**: no reduction of inputs in terms of fertilizers and pesticides • **Reproducing human system**: system characterized by the presence of a variety of work patterns (on-farm, off-farm and partially off-farm household typologies) and multi-functional land uses
Scenario 2 **Conventional agriculture**	• **Mono-functional land use**: agriculture (only agro-ecosystem) • **HEPA – High External Power Agriculture**: strongly market oriented, capital-intensive, highly mechanized, consuming large quantity of non-renewable resources (such as fossil fuels) • **Conventional agricultural methods**: no reduction of inputs in terms of fertilizers and pesticides • **Non reproducing human system**: system characterized by the presence of only agrarian seasonal work (mainly hired work from retired people) and mono-functional land uses
Scenario 3 **Eco-agriculture**	• **Mono-functional land use**: agriculture (only agro-ecosystem) • **HEPA – High External Power Agriculture**: strongly market oriented, capital-intensive, highly mechanized, consuming large quantity of non-renewable resources (such as fossil fuels) • **Organic agricultural methods**: reduction of inputs in terms of fertilizers and pesticides • **Non reproducing human system**: system characterized by the presence of only agrarian seasonal work (mainly hired work from retired people) and mono-functional land uses

The evaluation of the scenarios is carried out at two different levels, village and households. At the village level, the metabolism of the resulting land use systems is analyzed based on a comparative study considering at once their biophysical and socio-economic performances. At the household level the environmental, economic and social performances of different household typologies (off-farm, on-farm and partially off-farm) are compared, based on the main goals of development policies in the area of study (increasing the income per capita, reducing the human pressure on the environment, improving the social condition of the rural population).

4.7 Definition of typologies of households in Hongxing village

Multi-variate statistical techniques have been used for the purpose of the typification process based on information organized into a database (see table 22). The information used for the classification has been collected in a four months field work realized from October to January 2008 and refers to 104 rural households and 277 persons from Hongxing village. The information collected on the various variables refers to: human time, i.e. the time spent by each component of the household to perform their daily personal (eating, sleeping, personal care, leisure and education) and working activities (paid and non paid work), income generation according to farm and non-farm activities, food consumption, energy consumption, the size of the household (number of components) and finally the use of the land. The following table shows the main aspects considered during the interview realized with the head of each household included in the sample (see also appendix to chapter 4 for a detailed description of the questionnaires used).

Table 22 Main aspects considered during the interview

Basic household characteristics	Number of components Years of settlement in Chongming Age, gender and educational level of each member

Human Time (distributed in 24-hours day)	Working hours (hours/day)
	  Agriculture
	  Industry
	  Trade and Services
	  Aquaculture
	  Livestock
	  House working
	  Others
	Non working hours (hours/day)
	  Sleeping
	  Eating and personal care
	  Education and leisure (including transportation)
	  Others

Land use (ha)	House area (ha)
	Homestead area (ha)
	Agricultural area (ha)
	  Wheat
	  Rice
	  Corn
	  Vegetable
	  Fruit
	Husbandry area (ha)
	Others (ha)

Income generation (RMB/year)	Agriculture Industry Trade and Services Aquaculture (including fishing) Livestock Others
Expenditures (RMB/year)	Food Clothing Housing Furniture, electronic devices and cars Health care and medical services Education, cultural activities and recreation Others
Food consumption (kg/month)	Grains Meat and fish Vegetable Fruit
Energy consumption	Liquefied gas (kg/month) Fuel (liter/month) Firewood (kg/month)
Water consumption (ton/month)	

Technical information	Yield per crop (kg/mu/year)
	Subsistence agriculture (%)
	Rotation of crops
	  Type of crops and period of rotation
	  Growing time

Multi-variate statistical techniques have been performed through the realization of the following steps (Köbrich et al., 2003; Usai et al., 2006; Ottaviani et al., 2003):

1) Means and standard deviations were calculated and the informative variables with low variability were discarded, after a qualitative check of their relevance with respect to the objective of the research and the problem under investigation[30];
2) Observations with missing data were deleted from the sample (18);
3) Correlation was used to identify highly correlated variables ($R^2 \geq 0.90$) and eventually, depending on the significance of the variables with respect to the research objectives, to eliminate them from the analysis;
4) A Principal Component Analysis (PCA) was carried out to synthesize the informative variables in a reduced number of standardized variables displaying a large part of the total variability;
5) Finally a cluster analysis, using the Agglomerative Hierarchical Clustering (AHC) method, based on Euclidean distance and Ward's minimum variance criterion[31], was carried out for the aggregation of the observations in classes (clusters). The latter allowed obtaining the final typification of the rural households.

Table 23 Eigenvalues and variability

PC	Eigenvalues	Variability (%)
1	5,173	23,512
2	2,859	12,995
3	2,519	11,451
4	2,118	9,629
5	1,768	8,034
6	1,476	6,707
7	1,245	5,659
8	1,002	4,554
9	0,887	4,034
10	0,604	2,746
11	0,518	2,352

30 See the appendix to this chapter for a detailed explanation of the statistical procedure used to analyze the variables.

31 Ward's minimum variance method is related to the centroids method in which cluster centroids play an important role. At the beginning of the procedure, each object is on a distinct cluster, so that the distance to its cluster's centroid is zero; hence the sum of all these distances is also zero. As clusters form centroids move away from actual objects coordinates and the sums of the squared distances from the objects to the centroids increase. At each clustering step, Ward's method finds the pair of objects and or clusters whose fusion increases the sum over all objects of the squared distances between objects and cluster's centroids. Then the distance of object to the centroid is computed using the Euclidean distance formula (for a detailed description of the Ward's method applied to the clustering procedure see Legendre, 1998).

At the end of the previous analyses it has been possible to classify the 86 households left, after the deletion of 18 observations because of missing data, in 8 clusters by the use of 22 of the initial 45 variables.

The PCA method was used to extract linear combinations (principal components, PC) of the 22 variables, whose weights correspond to the eigenvectors of the correlation matrix. This made it possible to retain a small number of variables for the realization of the cluster analysis. The principal components with eigenvalues greater than 0.5 (Usai et al., 2006) were selected, they account for 91.67% of the total variability (see table 23) and therefore of the total information given by the original variables. Finally, based on the PC previously selected, the AHC was performed to obtain the 8 final clusters, whose dendrogram is showed in figure 29. The number of clusters, i.e. the cutting line, was decided with the intention to reduce as much as possible the number of clusters composed by only one observation. Various attempts and the examination of the different results from the point of view of the research objectives, allowed to decide for the cutting line which corresponds to the formation of 8 final classes. Following this procedure, just one cluster with one observation was obtained, representing a significant case for the area under investigation, as it is explained later in this section.

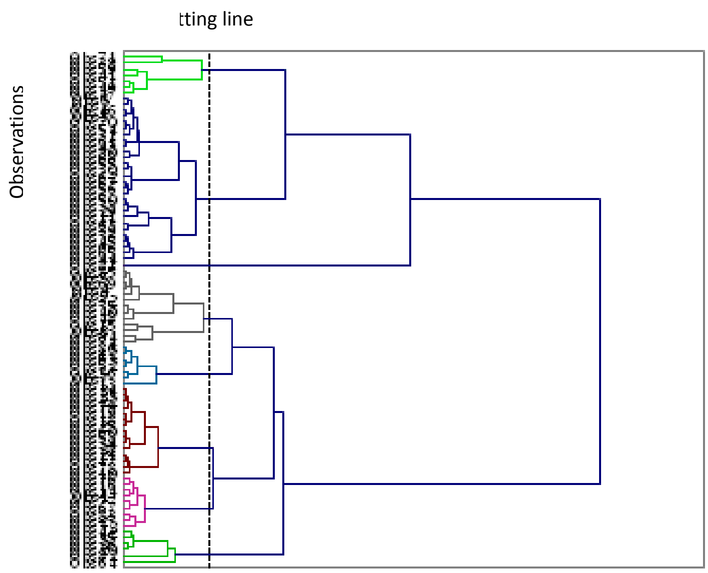


Figure 29 Dendrogram showing the cluster construction

The result of the clustering procedure was subsequently validated looking at the significance of the classes or categories with respect to the purposes of the study (Köbrich et al., 2003). This analysis showed a conceptual validity of the clustering procedure and made it possible to categorize the different classes according to a particular characteristic. In comparing the clusters it was seen that labor variables were very important in differentiating all classes. Consequently, the final classification reflects the type of household in relation to the income-generating activities. This allowed formulating a distinction between off-farm, on-farm and partially off-farm household types. Off-farm households are those who income generation depends upon activities realized completely out of the farm, such as industry or trade and services. On-farm households depend entirely on labor activities performed within the farm, such as cultivation, aquaculture and husbandry. Finally, partially off-farm households represent a combination between the previous two categories. Simultaneously, the clusters obtained reflect the intensity (very low, low, high, very high), in terms of the contribution of the different work activities to income generation. The ranges for the construction of the scale of intensity have been obtained by the use of the descriptive statistics calculated for each variable, such as: "mean", "upper bound on mean" and "lower bound on mean"[32]. This intensity made it possible an additional distinction within the classes. So, for example clusters 1 and 3 have been both classified as partially off-farm but they reflect a different intensity in terms of the contribution in income generation of off-farm employment participation of households in relation to hours of work (table 24).

Table 24 Clusters of selected households and classification

Clusters	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
No. of Observations	10	26	11	8	15	6	9	1
Classification								
Off-farm	-	x	-	-	-	-	x	-
On-farm	-	-	-	-	x	x	-	-
Partially off-farm	x	-	x	x	-	-	-	x
Activities' contribution to income generation								
Industry	very low	very high	-	very low	-	-	very high	-
Agriculture	very high	-	very high	very high	low	very high	-	very high
Trade & Services	-	-	-	-	-	-	very high	very high
Livestock	-	-	very low	very low	-	very high	-	-
Others*	very low	-	very high	-	low	low	-	-
Aquaculture	-	-	-	-	-	-	-	very high

*Others: pension and military subsidies, cleaner, accounting, green chemicals.

[32] See appendix 2 for a detailed explanation of the method and the scale used for the final evaluation.

According to the clustering and to the subsequent classification procedure, the cluster with a major number of observations/households, 30% c.a., have been classified as off-farm (C2) with very high intensity in terms of the realization of industrial activities. However, the sum of the households involved in agricultural activities is higher than the total number of off-farm households (51 versus 35 respectively). Only one household represented by cluster C8 shows the realization of aquaculture. This result is quite strange if we look at the official statistics of Chongming where aquaculture is an important sector in terms of income generation. Aquaculture and fishery constitute, in fact, the 31% of the total agricultural gross income (CMCSB, 2008) in Chongming. However, the same statistics show a reduction of 2.4% between 2006 and 2007. This result can be explained by the fact that in the island there is a further tendency to the abandonment of aquaculture in the face of an increment of off-farm jobs, such as industry and trade and services which allows households to reach higher incomes.

Based on the intensity values and on the analysis of the hours dedicated to the different activities, an additional typification has been done to easily visualize the rural households strategies in generating their income (table 25).

Table 25 Qualitative classification based on the main activity

Clusters	Classification
C1	Partially off-farm agriculture (POFag)
C2	Off-farm industry (OFin)
C3	Partially off-farm agriculture + others (POFagr+o)
C4	Partially off-farm others (POFo)
C5	On-farm crops (OFcr)
C6	On-farm livestock (OFlv)
C7	Off-farm trade and services (OFts)
C8	Partially off-farm aquaculture (POFaq)

Tables 26 and 27 describe the main characteristics of the clusters obtained, in terms of: human time, income generation, land use, life expenditures, food consumption, energy consumption, livestock activity, and household size.

Table 26 General information about the household's types collected in 2008

Clusters	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
HH's type	POFag	OFin	POFAgr+o	POFo	OFcr	OFlv	OFts	POFaq
HH size (average No. of members)	2.9	2.9	2.0	2.3	1.7	2.3	3.0	3.0
THA - Total Human Activity (hours per year)	25,404	25,269	17,520	19,710	15,184	20,440	26,280	26,280
Working hours (%)								
Agriculture	13	0	16	8	18	12	0	7
Industry	6	23	0	4	0	0	7	0
Trade & Services	0	0	0	0	0	0	16	15
Aquaculture	0	0	0	0	0	0	0	4
Husbandry	0	0	0	0	0	5	0	0
Others	0	0	5	7	0	0	0	0
Households' chores	9	9	7	13	8	9	9	6
Non working hours (%)								
Physiological overhead	44	46	45	45	48	47	45	42
Leisure & education	28	22	26	23	26	26	22	26
Total income, including virtual income (RMB/year)	18,647	31,607	17,424	15,806	8,296	13,532	42,400	51,916
On farm (%)								
Agriculture	57	0	82	27	88	75	0	15
Aquaculture	0	0	0	0	0	0	0	37
Husbandry	0	0	0	1	0	20	0	0
Off-farm (%)								
Industry	43	100	0	30	0	0	48	0
Trade & Services	0	0	0	0	0	0	52	49
Others (%)	0	0	17	43	12	6	0	0
Expenditures (RMB/year)	8,835.0	14,198.1	8,400.0	8,162.5	3,567.3	6,443.3	17,500.0	22,400.0
Total Available Land (ha)	1.237	0.027	1.683	0.635	0.763	0.931	0.024	1.654
Land use (ha)								
House area	0.009	0.010	0.007	0.008	0.008	0.008	0.008	0.009
Homestead area	0.018	0.017	0.015	0.016	0.016	0.013	0.016	0.018
Agricultural area	0.605	0.000	0.830	0.306	0.369	0.455	0.000	0.813
Wheat	0.023	0.000	0.091	0.073	0.012	0.067	0.000	0.067
Rice	0.031	0.000	0.094	0.073	0.021	0.056	0.000	0.133
Corn	0.273	0.000	0.297	0.074	0.151	0.128	0.000	0.080
Vegetable	0.277	0.000	0.342	0.082	0.184	0.203	0.000	0.133
Fruit	0.000	0.000	0.006	0.005	0.000	0.000	0.000	0.000
Pond	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400
Pasture	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Livestock number								
Sheep	0.20	0.00	0.27	0.63	0.00	4.17	0.00	0.00
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: own elaboration on data from Hongxing village, 2008

Table 27 Technical coefficients: food, energy and water consumption, household types

Clusters	C1	C2	C3	C4	C5	C6	C7	C8
HH's type	POFag	OFin	POFAgr+o	POFo	OFcr	OFlv	OFts	POFaq
Food Consumption (kg/year)								
Grains	607	603	418	471	363	488	627	627
Meat and fish	183	182	126	142	109	147	189	189
Vegetable	861	857	594	668	515	693	891	891
Fruit	84	84	58	65	50	68	87	87
Energy consumption								
Electricity (kW/month)	35.0	56.5	41.8	30.0	16.5	32.2	35.3	50.0
Liquefied gas (kg/month)	17.0	17.4	17.3	7.0	10.2	31.3	12.2	15.0
Fuel (liter/month)	2.0	5.0	0.9	0.0	0.3	0.0	8.1	15.0
Firewood (kg/month)	25.0	0.0	0.0	0.0	113.3	25.0	0.0	0.0
Water consumption (ton/month)	9.7	0	12.4	6.8	6.0	12.4	0	20.0

Source: own elaboration on data from Hongxing village, 2008

4.8 The MuSIASEM approach applied to the analysis of rural systems. The case of Hongxing village, China

In this section the MuSIASEM approach has been applied to the analysis of Hongxing village. It is illustrated, in particular, an analysis of "what the system is" and "what the system does" taking the village as the focal level of analysis. As pointed out before, the system under investigation is characterized across scales based on the following variables: human time, land use, monetary flow and energy flow. These variables allow to analyze Hongxing village taking into account simultaneously a "socio-economic reading" and a "biophysical reading". Figure 30 shows a simplified illustration of Hongxing village based on the parallel representation of fund (human activity and land use) and flow variables (monetary and energy flows). The system is composed by the community, i.e. the society expressed by the use of the time (hours of human activity: physiological overhead – PO, leisure and education – L&E, paid work – PW, subsistence – SUB, household chores – HC), and the agro-ecosystem expressed by the different land uses (agriculture, human settlements). The arrows represent the interaction between the components of the system (community and agro-ecosystem) and between the system and the external socio-economic and environmental contexts (respectively outside the system, market and ecosystem). In particular, the system interacts with the external contexts through the exchange of money, food, inputs of production and hours of human activity.

At the same time it releases in the ecosystem substances derived by the process of production (i.e. nitrogen and pesticides). Finally, all the activities realized by the system are sustained by the consumption of energy (endosomatic and exosomatic energy). Endosomatic energy is generated through the metabolic transformation of food energy into muscle energy in the human body. Exosomatic energy is generated by transforming energy outside of the human body, such as burning gasoline in a tractor[33].

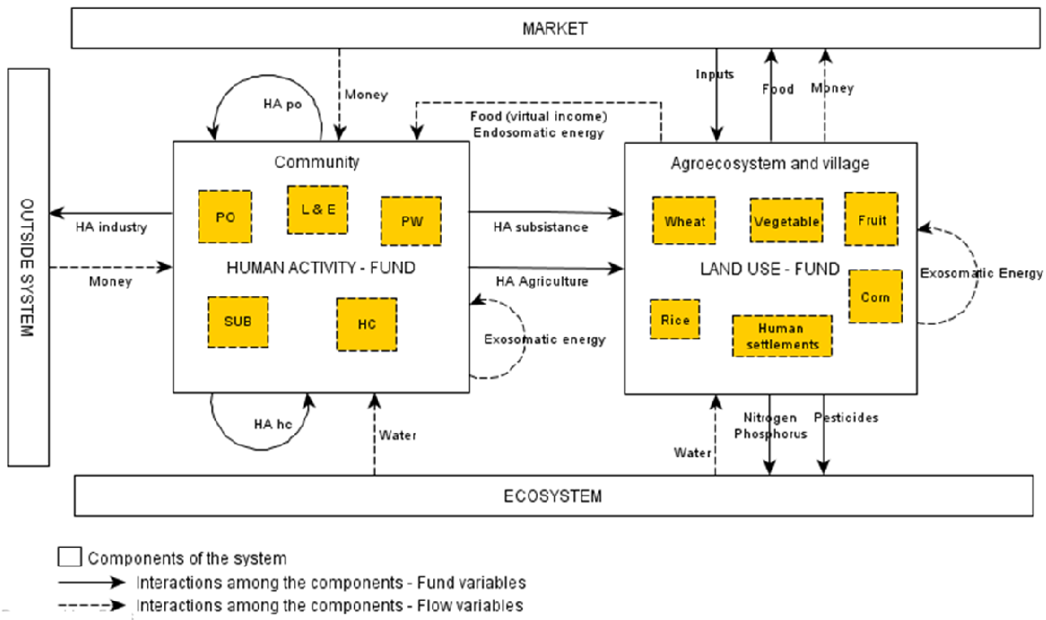


Figure 30 Representation of Hongxing village system using fund and flow variables

It will be showed later on in this chapter how the representation of the fund and flow variables described in figure 30 makes it possible to achieve two different objectives:

1) to derive and evaluate multidimensional indicators that represent the performance of the system in terms of its interaction with the external socio-economic and environmental contexts;
2) to perform a multi-scale analysis based on the evaluation of multidimensional indicators at different scales.

The characterization of the system under investigation represented by figure 30 starts with the definition of the meta-agents taken into consideration. Meta-agents (aggregation of individual agents) represent the categories or entities, which have the prerogative to describe the system in a simplified way (see chapter 1 for a detailed explanation of this

[33] In this case only exosomatic energy is evaluated since endosomatic energy can be considered approximately the same for each individual.

aspect). The meta-agents taken into consideration in this case are: the village, the economic sectors, the households, the various uses of the land. Each meta-agent is described by the use of variables representing flows and/or funds. The information at the higher levels is obtained by a process of aggregation of the information at the lower levels, e.g. information at the level n, the village level, is obtained by an aggregation of the information obtained at the household level. So, based on the identification of typologies of households and their distribution with respect to the focal level of analysis it has been possible to make estimations about the higher levels. The process follows a bottom-up estimation procedure. In the following sections the results of the estimation procedure with the corresponding quantitative analysis of the fund and flow variables across scales is provided. These quantitative evaluations across scales represent the basic quantitative information for the calculation of the evaluation criteria scores.

4.8.1 Multi-level representation of the fund human activity

The meta-agents taken into consideration in this case are: the community (level n), the "paid work" and "non paid work" sectors (level n-1), the sub sectors for both the paid work (agriculture, industry, trade and services) and non paid work sectors (household chores, leisure and education, sleeping and personal care) (level n-2) and finally the household typologies (level n-3). These meta-agents are organized in a multilevel matrix such as the one represented in figure 22.

The fund Total Human Activity (THA) at the community level (n) represents "what the system is", in other words the size of the focal level of analysis expressed in terms of hours (total population x 8760, that are the total number of hours available in a year for each individual). Then, based on the demographic structure of the population organized in structural types (age classes) and on the information related to the use of time by these structural types, it has been possible to estimate the categories in which each meta-agent is composed (e.g. the hours of the paid work sector in relation to agriculture, industry and trade and services). In other words, the estimation of the values obtained at the various levels depend on the demographic distribution of the population at the village level per age classes and on the information related to their distribution of time into various activities. In the case presented, each structural type allocates its total endowment of HA into the following categories.

1) HApw, which is the human time dedicated to paid work activities (PW), in this case we distinguish in agriculture, industry and trade and services:
2) HAnopw, which is the human time dedicated to non paid work activities, such as household chores (HC), leisure and education (L&E), sleeping and personal care (PO).

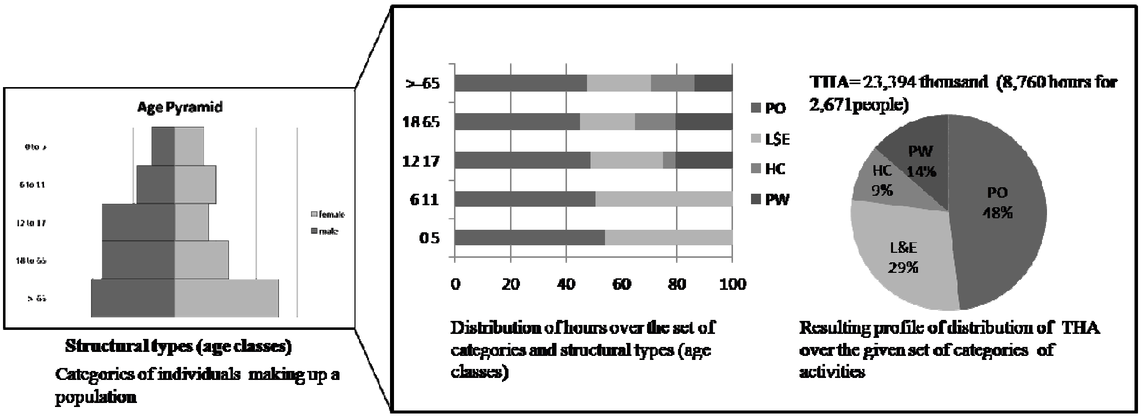


Figure 31 Representation of the fund "human time" over structural types and functional categories at the individual level (Source: adapted from Giampietro et al., 2008). Data from Hongxing village, Chongming island, China.

Data of figure 31 refer to Hongxing village. The same representation can be applied also at the level of household typologies (n-3). In this case individuals are grouped into typologies of households determining the distribution of the human time over the functional categories used above. Based on the distribution of household typologies with respect to the focal level of analysis and on their use of the time over the set of human time categories defined before, it is possible to estimate the aggregate value at the higher level of sub sectors (n-2) (agriculture, industry, trade and services, physiological overhead, leisure and education, household chores) and, scaling up again, at the level of the two sectors paid work and non paid work (n-1) (figure 32). All this process follows the congruence constraint expressed by equation 1 in relation to the human time variable. This mechanism of "scaling" makes possible a characterization of the population, and in this case of the village under investigation, in terms of individuals, households and economic sectors using the same functional categories across scales. As we will see later in this chapter, this way to represent fund and flow variables allows to analyze the system under investigation considering in parallel a "socio-economic reading" (represented respectively by the fund human activity and the monetary flow) and a "biophysical reading" (represented by the fund land use and the energy flow) and focusing on trade-offs related to the realization of possible scenarios of development of the rural village under investigation, Hongxing.

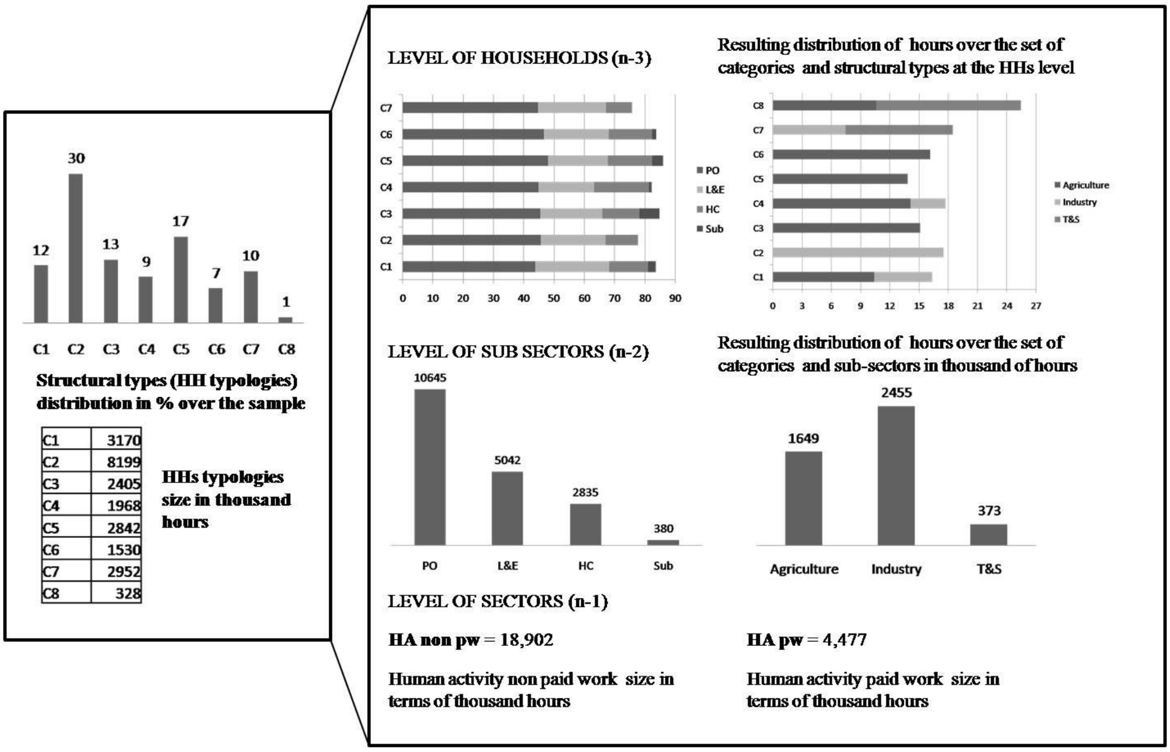


Figure 32 Representation of the fund "human time" over structural types and functional categories at the HHs, sub sector and sector levels. Data from Hongxing village, Chongming island, China.

4.8.2 Multi-level representation of the monetary flow

This section describes the representation of the monetary flow across scales. The analysis follows the same rational explained in the previous section related to the fund human activity. The monetary flow is represented by the gross income[34], which is the total income produced by the various working activities (agriculture, industry, trade and services) of the household typologies and the "virtual income". The latter represents the monetary value of subsistence agriculture and it has been estimated based on the market prices of the food products cultivated and consumed directly by the households. In other

[34] The gross income indicates the monetary flows that enter the system under investigation through wages and at the same time leave the system through expenditures. In other words, it represents the monetary flow that supports the system from an economic point of view. It is the monetary base supporting the activities of people and the system in general based on the fact that all expenditures from individuals become the income of the businesses, and the expenditures of the businesses become the income of the individuals.

words, the “virtual income” is the fraction of the households income used for subsistence purposes. In figure 33, each level is analyzed in terms of the gross income related to the household typologies and distributed over working (agriculture, industry and trade and services) and non working activities (virtual income).

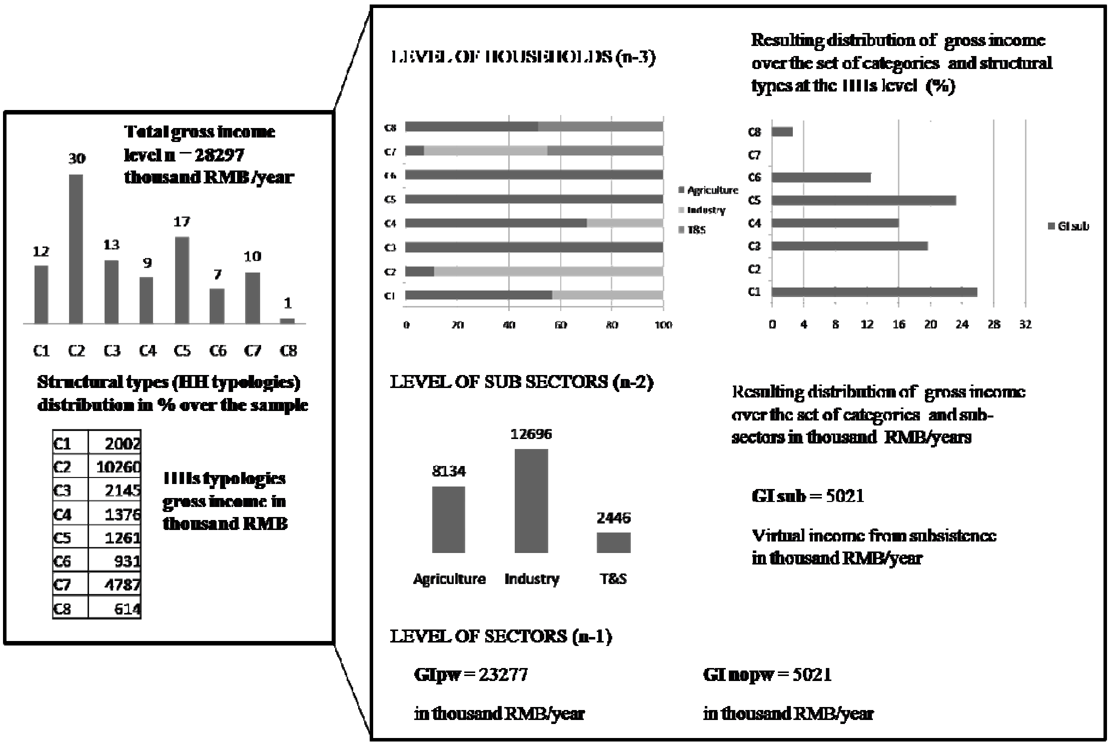


Figure 33 Representation of the flow “gross income” over structural types and functional categories at the HHs, sub sector and sector levels. Data from Hongxing village, Chongming island, China.

4.8.3 Multi-level representation of the fund land use

This section provides a representation of the fund “land use” across scales. This variable is analyzed by the use of the following functional categories:

1) Total Available Land - TAL, which is the total land available at the level n, in this case the village level;
2) Ecological Overhead Available Land – EOAL, which represents the fraction of the land non colonized by humans, such as natural parks (level n-1);
3) Colonized Land- COL, which is the fraction of TAL used for the realization of human activities. The latter is composed by the land in agricultural production (LIAP) and the land not in agricultural production LNAP (level n-2). LIAP is then

composed by the land in agricultural production for subsistence purposes (LIAP sub) and for cash (LIAP $) (level n-3). While, LNAP is composed by the land used for human settlements (LNAP hs) and for cash (LNAP $) (level n-4). The latter could be the case of the fraction of land used for industrial purposes.

A representation of the fund "land use" across scales is showed in the following figure 34. The rational for the construction of the multi-level matrix, this time for the variable "land use" is the same of that used in relation to the variables "human time" and "gross income" showed in figure 22.

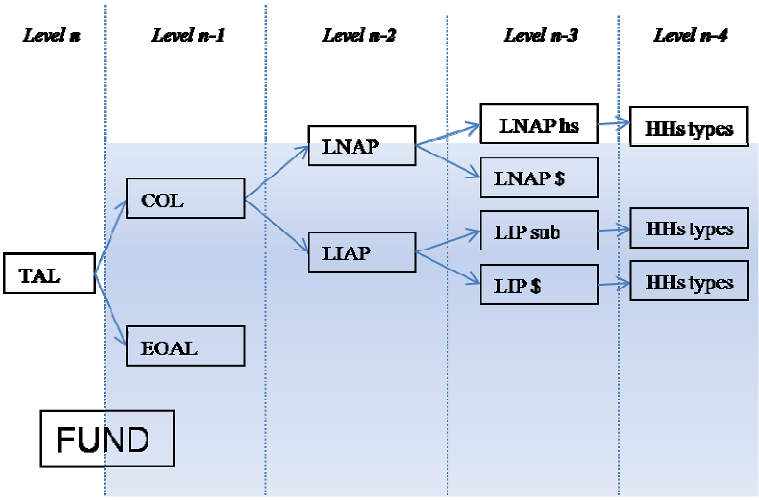


Figure 34 Multi-level matrix of the fund "land use"

Figure 35 shows the representation of the multi-level matrix "land use" based on data collected in Hongxing village. Each level represents an aggregation of the value obtained at the lower levels respecting the coherence relation across scales that characterize the construction of a multi-level matrix. At the level of households the land is used for two main purposes: agricultural production and human settlement. While at the level of the village additional land use categories characterize the system, such as the protected land and the land used for industrial production.

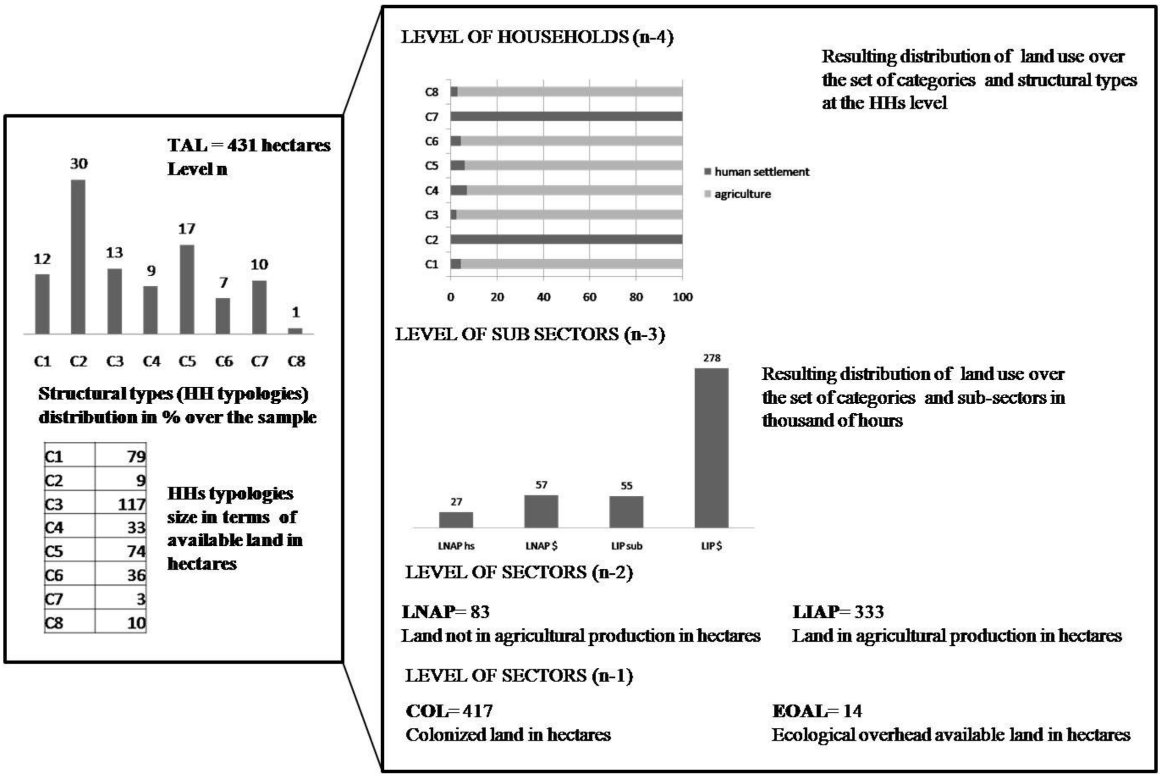


Figure 35 Representation of the fund "land use" over structural types and functional categories at the HH, sub sector and sector levels. Data from Hongxing village, Chongming island, China.

4.8.4 Multi-level representation of the energy flow

This section provides a representation of the flow "energy throughput" across scales. This variable is analyzed by the use of the following functional categories:

1) Total Energy Throughput - TET, which is the total energy used at the level n, in this case the village level;
2) Energy Throughput paid work – ET pw, which represents the fraction of the energy used by the paid work sector (level n-1). In this case I considered only the energy used in agriculture and derived by the use of fertilizers, since farmers at the small scale don't generally use tractors for agricultural production;
3) Energy Throughput not paid work – ET no-pw, which is the fraction of the TET used for the realization of non working human activities, such as leisure and education, household chores, physiological overhead, and finally the energy used for the realization of subsistence agriculture (in terms of the use of fertilizers and pesticides).

A representation of the flow "energy throughput" across scales is showed in the following figure.

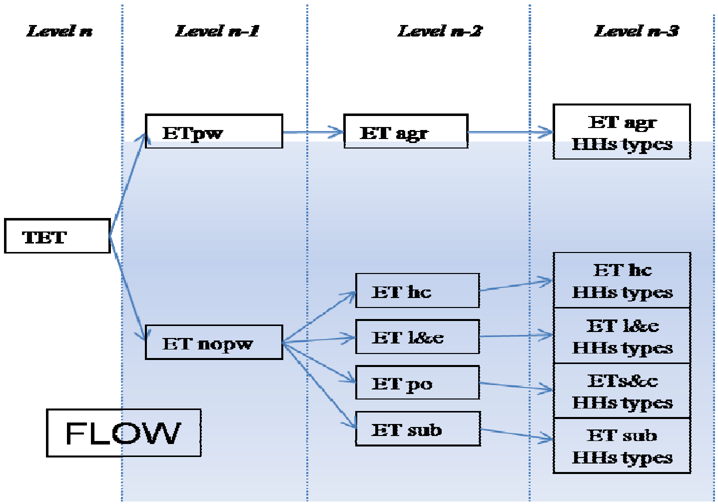


Figure 36 Multi-level matrix of the flow energy throughput

Figure 37 shows the representation of the multi-level matrix related to energy throughput based on data collected in Hongxing village.

In the case of the energy consumed in the "non paid work sector" the information used is the one indicated in table 27 at the voice "energy consumption" per each household typology.

While, for the energy throughput calculation in the agricultural sector, information, related to the use of fertilizers per types of crop, has been collected per hectares asking directly to agricultural technicians working in the village. For that reason, the quantity per hectares results the same for each household, while the total consumption depends on the amount of hectares cultivated per crops.

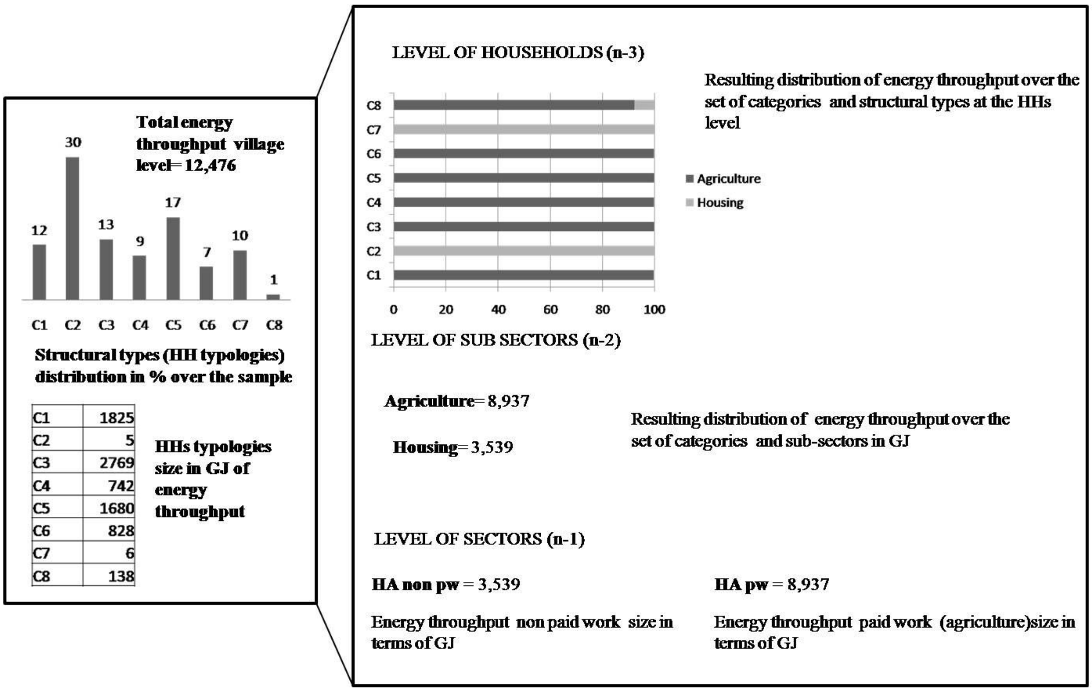


Figure 37 Representation of the flow "energy throughput" over structural types and functional categories at the HH, sub sector and sector levels. Data from Hongxing village, Chongming island, China

As we will see in the following sections, the multi-level representations based on the realization of a bottom-up estimation procedure have been useful for the calculation of the criteria scores at the two main levels, Hongxing village and household, for the analysis of the different scenarios of development.

4.9 Identification of the evaluation criteria

The criteria selected for the analysis of the different scenarios of development have been used to evaluate to what extent each scenario contributes to accomplishing the various development goals defined by policy institutions and their coherence across scales. For that reason, each criterion represents an indicator reflecting one or the other of the policy objectives across scale, from the national to the local scale. Table 28 shows the policy options and the corresponding criteria selected for the final evaluation.

The criteria have been put together according to different dimensions of analysis, economic, environmental and social respecting the multidimensional characteristic of development policies across scales, which in synthesis call for the simultaneous realization of the following objectives: economic development, food security, environment protection and natural resources conservation.

Table 28 Rural development policies and evaluation criteria

Dimensions and criteria	Related policy goals	Scale of the policy
Economic Dimension		
1) Labor Productivity	Economic development	National
2) Net income	Increasing the income per capita	Local
Social dimension		
3) Food self-sufficiency[35]	Food security	National
4) Diversification of risk	Increasing urbanization	Local and Regional
5) Quality of life	Increasing education	Local
Environmental dimension		
6) Use of pesticides 7) Nitrogen use 8) Energy intensity	Good management of natural resources, environmental protection, reducing pollution on soil	All scales

Evaluation criteria and indicators don't follow at this time, differently from the case presented in the second part of this thesis, the social actors' objectives and expectations using a participatory approach. Instead, they reflect the development goals defined at various political levels.

Table 29 Evaluation criteria: unit of measurement and description

Evaluation criteria	Unit	Description
Labor productivity	RMB/hour	Income generated per hour of work
Energy intensity	MJ/hour	Energy use per unit of human activity
Net income	RMB/year	Gross income generated by the household minus life expenditures
Food self-sufficiency	%	Percentage of food self-sufficiency or % of independence from market for food consumption
Quality of life	%	Percentage of hours dedicated to non working activities such as leisure and education over total disposable hours in a year
Use of pesticides	kg/ha/year	Use of chemical pesticides per unit of land in kilograms in a year
Nitrogen use	kg/ha/year	Amount of nitrogen utilized in agriculture per unit of land in a year
Diversification of risk	%	Percentage of income from non-farm activities over the total income

[35] The concept of food self-sufficiency is generally taken to mean the extent to which a country can satisfy its food needs from its own domestic production. It differs from food security because it looks only at national production as the sole source of supply. On the contrary, food security takes into account commercial imports and food aid as possible sources of commodity supply. In other words, food self- sufficiency is one of the components of food security (FAO, 1999).

For what concerns the identification of the specific indicators listed in the previous table, I decided to use at the same time what is normally used for the analysis of development of rural areas (labor productivity, net income) (OECD, 2001), but also specific indicators related to the particularities of the area under investigation.

In particular, two indicators, labor productivity and net income, have been used to represent the goal of Chongming development policies to reduce the gap between the income level of rural and urban people. The huge gap between urban and rural people in terms of disposable income is in fact one of the main consequences of the rapid economic growth of China and one of the main causes of the social instability that recently characterize the Chinese society (Wang, 2009). While, for what concerns the goal "environment protection and natural resources conservation", I decided to use indicators referring to energy and soil. Impacts on the soil have been analyzed by the use of pesticides (the use of a huge amount of pesticides represent one of the main sources of soil pollution in Chongming) and nitrogen (high levels of nitrogen are related to the increase of nitrates and to the consequent increase of the salinization of soil which is one of the major environmental impacts of agriculture in Chongming). While, the energy source has been analyzed by the intensity in which the resource is used. The other factors, such as: food self-sufficiency, quality of life, and risk diversification are of paramount importance particularly for rural households in developing countries or in rapidly changing realities such as the rural areas of China. Rural households in these areas are in fact particularly sensible to market fluctuations related to food products and to the rapid increase of the level of urbanization (especially in China where, according to the People's Daily Journal, during the twenty-six years between 1980 and 2006, the level of urbanization increased on average by 0.9 percent per year. Nearly 10 million people from the rural population moved to urban areas each year). These aspects influence strongly the propensity of rural households to a diversification of their income among various off-farm activities, which simultaneously has an influence on the food self-sufficiency of the rural households in terms of food production (food security) and on the quality of life in terms of the time dedicated to non-working activities.

In rapidly changing circumstances the traditional vision of rural economies as purely agricultural is not representative of the reality. Farm households across the developing world earn an increasing share of their income from off-farm sources. And the specialized off-farm or partially off-farm households that emerge often diversify into multiple business activities becoming a multi-activity rural household (Reardon et al. 2006;

Berdegue et al., 2001; Abdulai and CroleRees, 2002). Consequently, a fuller understanding of off-farm enterprise dynamics requires an assessment of the household decision-making environment within which these decisions are frequently made.
Table 29 shows a summary and a description of all the indicators used for the calculation of the evaluation criteria previously selected.
In synthesis, the multidimensional indicators have been used with the purpose to represent a complex reality made up by different domains (economic, ecological and social), such as the case of Chongming rural areas subjected to rapidly changing circumstances.

4.10 Data collection

Once the criteria and relative indicators have been determined the next step for the construction of the impact matrices related to each of the policy scenarios, is the attribution of evaluation criteria scores. In this case the majority of the indicators have been evaluated in quantitative terms using information coming from the realization of a four month fieldwork in Shanghai and Chongming. In particular, the information collected has been related to: human time, income generation, land use, expenditures, food, energy and water consumption, and finally on technical information related to the agricultural activity (see tables 26 and 27). Data have been collected by the use of a questionnaire on a sample of 104 households for a total of 277 people in Hongxing village.
To each head of the households interviewed was asked to give information related also to the other members of the same household. Following this procedure it has been possible to collect more data for what concerned the use of the time for the realization of all the working and non-working activities performed in a 24-hours day. Differently, the other information relates to the entire household, such as: income generation, expenditures, food, energy and water consumption and finally land use. Information, useful for the calculation of the environmental indicators, such as nitrogen use in agriculture, use of pesticides and water use in agriculture, have been collected asking to agricultural technicians in Hongxing village for the following information: pesticides in kilograms per hectare per crop, water use in volume per hectare per crop, and finally fertilizer use per hectare per crop. While information related to Hongxing village, such as the number of inhabitants per age classes and the land use, has been collected by means of a questionnaire submitted to the head of the village (see appendix to this chapter for a detailed description of the various questionnaires used for the collection of the data).

4.11 Attribution of the criteria scores: Hongxing village (BAU scenario) and household typologies

Based on data collected by means of questionnaires submitted to different stakeholders at different levels (households, head of Hongxing village and various agricultural technicians) it has been possible to attach a value to each of the evaluation criterion listed in table 29. All the indicators have been evaluated quantitatively except for the diversification of risk. Next sections provide an explication of the evaluation procedure followed per each criterion and the final results obtained.

4.11.1 Net income (household level)

The net income indicator has been evaluated at the households' level based on the following equation:

$$Y = \sum_{i=1}^{n} (Y_i + vi) - \sum_{i=1}^{p} E_i$$

In which Y represents the sum of the incomes generated in a year by the household from different working activities (n) and the virtual income (vi), which is the income derived by food self-sufficiency, minus the sum E of the different expenditures (p), such as the money spent in a year for the following items: food, clothing, furniture, electronic devices and cars, health care and medical services, education, cultural activities and recreation. Taxes and subsidies are not included since there is no relevant difference in the amount paid and received between the various households.

In particular, the "virtual income" voice (see table 30) has been evaluated based on the information collected at the household level related to the fraction of the various agricultural products auto-consumed by the household and their average market prices.

Table 30 Virtual income household typologies

Household typologies	Virtual income (RMB/year)
C1 - Partially off-farm agriculture	7,734
C2 - Off-farm industry	0
C3 - Partially off-farm agriculture + others	11,048
C4 - Partially off-farm others	3,050
C5 - On-farm crops	5,607
C6 - On-farm livestock	5,302
C7 - Off-farm trade and services	0
C8 - Partially off-farm aquaculture	2,351

Source: data from Hogxing village, Chongming island, China

This indicator has been evaluated only at the household level to have specific information related to the impacts of the development scenarios on the disposable income of the various household typologies (table 31).

Table 31 Net income household typologies

Household typologies	Net income (RMB/year)
C1 - Partially off-farm agriculture	9,812
C2 - Off-farm industry	17,409
C3 - Partially off-farm agriculture + others	9,024
C4 - Partially off-farm others	7,644
C5 - On-farm crops	4,729
C6 - On-farm livestock	7,089
C7 - Off-farm trade and services	24,900
C8 - Partially off-farm aquaculture	29,516

Source: data from Hogxing village, Chongming island, China

4.11.2 Labor productivity (household and village levels)

The labor productivity (LP) indicator represents the productivity of the system under investigation per hour of human activity. Using the concepts of intensive and extensive variables explained in paragraph 3.8.2, the LP indicator can be defined as an intensive variable obtained by the ratio between the two extensive variables human time and gross income (LP = GI/HA). The gross income represents the sum of the gross incomes generated by human activities in the paid work sectors (agriculture, industry, trade and services) in a year including also the virtual incomes.

The multi-scale representation of the two variables, human time and gross income (income generated by working activities), presented in paragraphs 4.8.1 and 4.8.2, makes it possible the evaluation of LP across scales. So, in this case we have information related to the LP of the various household typologies but also of the various economic sectors and finally of Hongxing village.

Next figures show, using a four angles diagram[36], how, using the concept of multi-level matrices it is possible to represent the indicators LP across scales, using the variables human time (fund) versus gross income (flow). The example refers to the village, economic sector and sub sector levels. The same representation can be extended to the households' level (n-3), following the same rational.

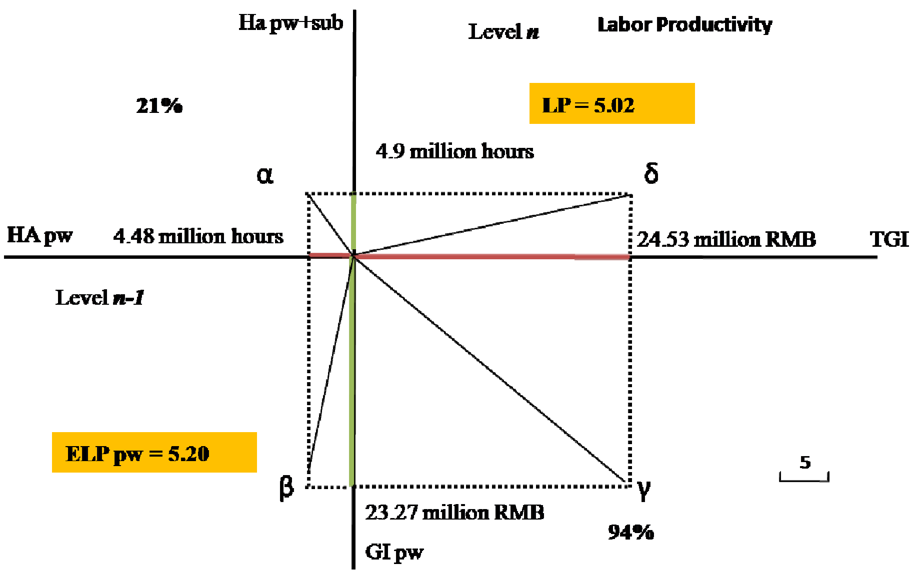


Figure 38 Establishing a bridge across different hierarchical levels, gross income versus human time at levels n and n-1

[36] For a more detailed explanation of the formalization of the four angles diagram used see Giampietro, 2003; Giampietro and Mayumi 2000a and 2000b.

In the previous figure, the axes represent the hours of human activity and income at the various scales. While, the angles (δ, γ, β, and α) represent the intensive variables, i.e. the ratios between the variables. Therefore, the angle δ in the upper-right quadrant of the graphic in figure 38 refers to the labor productivity of the system at the village level (n), given by the ratio between the total gross income expressed in million RMB and the total human activity expressed in million hours. In other words, the income generated at the level of Hongxing village per hour of human activity. The angle γ in the lower-right quadrant depends on the fraction of TGI generated by the paid work sector at the level n-1. Similarly, the angle α in the upper-right quadrant depends on the fraction of THA dedicated to the paid work sector. Finally, the angle β in the lower-left quadrant indicates the labor productivity of the paid work sector at the level n-1.

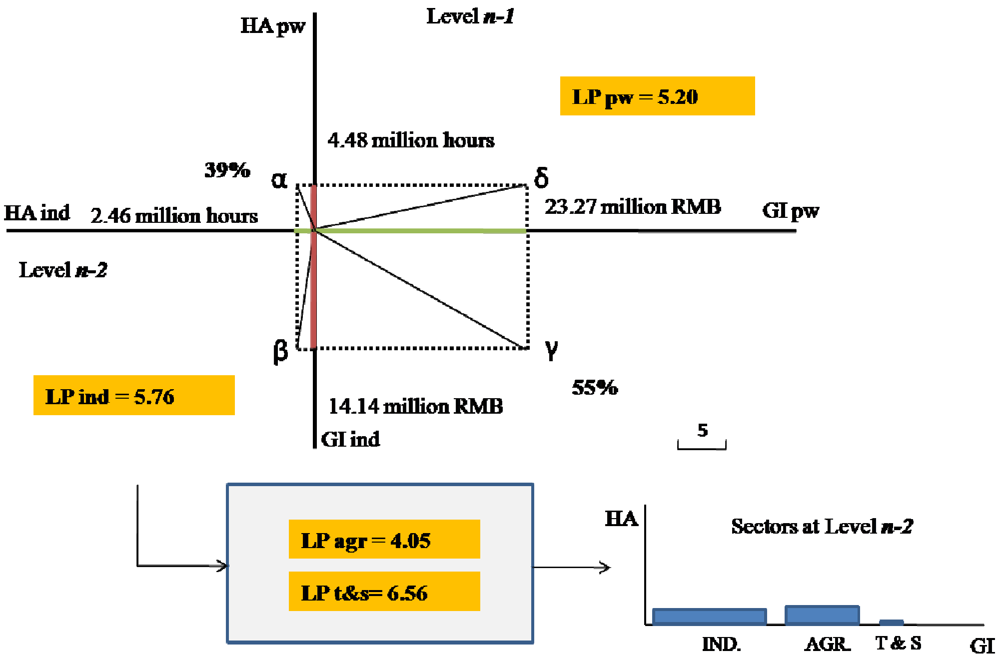


Figure 39 Establishing a bridge across different hierarchical levels, gross income versus human time at levels n-1 and n-2.

Following the previous explanation, we can have an illustration of the same variables at the lower level n-2, which is the level of the economic sectors (agriculture, industry and trade and services). This process of scaling down is illustrated in figure 39, in which the

LP of the industrial sector is illustrated. The latter in turn can be compared with the same intensive variables calculated for the other two sectors, agriculture and trade and services. The representation across scales illustrated in figures 38 and 39 gives us the opportunity to integrate quantitative descriptions referring to different dimensions of analysis and at the same time to obtain benchmark values for the characterization of the system from an economic point of view (table 32).

Table 32 Labor Productivity (LP): all levels

Levels n, n-1, n-2, n-3	**LP (RMB/hour)**
Household typologies (n-3)	
C1 - Partially off-farm agriculture	3.89
C2 - Off-farm industry	5.63
C3 - Partially off-farm agriculture + others	4.58
C4 - Partially off-farm others	4.30
C5 - On-farm crops	3.12
C6 - On-farm livestock	3.77
C7 - Off-farm trade and services	6.84
C8 - Partially off-farm aquaculture	7.74
Trade and Services sector (n-2)	6.56
Industrial sector (n-2)	5.76
Agricultural sector (n-2)	4.05
Paid work sector (n-1)	5.20
Village (n)	5.05

Source: own elaboration on data from Hogxing village, Chongming island, China

4.11.3 Quality of life (household and village levels)

The indicator "quality of life" has been used to analyze the policy goal "increasing education". It represents the fraction of the non working time people dedicate to leisure and education over the total available time. Thanks to the multi-level representation of the fund human activity across scales (see paragraph 4.8.1) it has been possible to evaluate the indicator at both the household and village levels (table 33).

Table 33 Quality of life household and Hogxing village levels

Levels	Quality of life (%)
Household typologies (n-3)	
C1 - Partially off-farm agriculture	28
C2 - Off-farm industry	22
C3 - Partially off-farm agriculture + others	26
C4 - Partially off-farm others	23
C5 - On-farm crops	26
C6 - On-farm livestock	26
C7 - Off-farm trade and services	22
C8 - Partially off-farm aquaculture	26
Village level (n)	**25**

Source: own elaboration on data from Hogxing village, Chongming island, China

4.11.4 Food self-sufficiency (household and village levels)

The "food self-sufficiency" indicator refers to the agricultural production auto-consumed by the household typologies to satisfy their basic needs in terms of food consumption. The evaluation has been based on the following information collected at the household level:

1) the fraction of the various agricultural products produced and sell to the market;
2) the consumption of food products per capita in a year.

The ratio of food consumed yearly by the household members that is supplied by domestic production represents the food self-sufficiency indicator (in percentage). This value has been evaluated at the household and village levels.

Table 34 Food self-sufficiency in percentage values. Hongxing village and household typologies

Levels	**Food self-sufficiency (%)**
Household typologies (n-3)	
C1 - Partially off-farm agriculture	89
C2 - Off-farm industry	0
C3 - Partially off-farm agriculture + others	89
C4 - Partially off-farm others	89
C5 - On-farm crops	89
C6 - On-farm livestock	95
C7 - Off-farm trade and services	0
C8 - Partially off-farm aquaculture	89
Village level (n)	**76**

Source: own elaboration on data from Hogxing village, Chongming island, China

This indicator has been evaluated also in terms of hectares of land (see the multi-scale representation of the fund land use in figure 34) dedicated to food self-sufficiency purposes and in monetary terms by the use of the "virtual income" concept explained in paragraph 4.11.1.

4.11.5 Diversification of risk (household and village levels)

The indicator "diversification of risk" has been evaluated based on the analysis of the fractions of the income generated by off-farm and on-farm activities. Higher is the balance between the two percentage values obtained, higher is the diversification of risk attached to the household typologies. This indicator is the only one evaluated using a qualitative scale based on the following categories: very high, high, medium, low and very low. Each category is associated to a range determined on a numerical scale going from 0 to 100. The quantitative scale with the associated qualitative values used is represented in the following figure:

Table 35 Diversification of risk household typologies and village

Household typologies	% off-farm	% on-farm	Difference	Diversification of risk
C1 - Partially off-farm agriculture	43	57	13	very high
C2 - Off-farm industry	100	0	100	very low
C3 - Partially off-farm agriculture + others	17	83	65	low
C4 - Partially off-farm others	73	27	46	medium
C5 - On-farm crops	0	100	100	very low
C6 - On-farm livestock	0	100	100	very low
C7 - Off-farm trade and services	100	0	100	very low
C8 - Partially off-farm aquaculture	49	51	2	very high
Village level (n)	**68**	**32**	**35**	**high**

Source: own elaboration on data from Hogxing village, Chongming island, China

The qualitative values have been attached to each household typology based on the difference between the fractions of off-farm and on-farm income generating activities: less is the absolute difference between the two fractions more is the diversification of risk of the household type (table 35).

4.11.6 Use of pesticides (household and village levels)

This indicator measures the total amount of chemical pesticides used by farmers in a year expressed in kilograms.

Since the consumption of pesticides don't differ considerably among farmers, data used for the evaluation of this indicator have been collected by asking to the agricultural technicians in Hongxing village for the average amount consumed by farmers per crop per hectare. As a consequence, differences in the final amounts of pesticides used by the different typologies of households depend on the hectares of land they cultivate rather than on the absolute amount consumed per hectare.

Table 36 Pesticides use, household and village levels

Levels	**Use of pesticides (kg ha^{-1} year^{-1})**
Household typologies	
C1 - Partially off-farm agriculture	4.2
C2 - Off-farm industry	0
C3 - Partially off-farm agriculture + others	5.9
C4 - Partially off-farm others	2.3
C5 - On-farm crops	2.6
C6 - On-farm livestock	3.3
C7 - Off-farm trade and services	0
C8 - Partially off-farm aquaculture	3.4
Village level	**7.0**

Source: own elaboration on data from Hogxing village, Chongming island, China

4.11.7 Nitrogen use (household and village levels)

This indicator measures the quantity of nitrogen consumed by the households for the realization of agricultural practices. The differences in nitrogen used between the various household typologies depend on the hectares of land in agricultural production and the types of crops.

This indicator results particularly important in Chongming since the process of salinization is one of the main environmental pressure on the soil resource due to both the realization of inappropriate cultivation practices and the infiltration of salt water from the East China Sea. The use of nitrogen is in fact related to the increase of nitrates and to the consequent increase of the salinization of soil in terms of salt concentration (MA, 2005).

Table 37 Nitrogen use in agriculture, household and village levels

Levels	**Nitrogen use (kg ha^{-1} year^{-1})**
Household typologies (n-3)	
C1 - Partially off-farm agriculture	286
C2 - Off-farm industry	0
C3 - Partially off-farm agriculture + others	288
C4 - Partially off-farm others	289
C5 - On-farm crops	288
C6 - On-farm livestock	288
C7 - Off-farm trade and services	0
C8 - Partially off-farm aquaculture	150
Village level (n)	**284**

Source: own elaboration on data from Hogxing village, Chongming island, China

4.11.8 Phosphorus use (household and village levels)

This indicator measures the quantity of phosphorus consumed by the households for the realization of agricultural practices. The estimation procedure follows the same rational applied for the calculation of the nitrogen and pesticide use indicators.

This indicator has been only used for the estimation of the energy intensity indicator (see the following section 4.11.9).

Table 38 Phosphorus use in agriculture, household and village levels

Levels	**Phosphorus use (kg ha^{-1} year^{-1})**
Household typologies (n-3)	
C1 - Partially off-farm agriculture	103
C2 - Off-farm industry	0
C3 - Partially off-farm agriculture + others	101
C4 - Partially off-farm others	95
C5 - On-farm crops	105
C6 - On-farm livestock	102
C7 - Off-farm trade and services	0
C8 - Partially off-farm aquaculture	49
Village level (n)	**134**

Source: own elaboration on data from Hogxing village, Chongming island, China

4.11.9 Energy intensity (household and village levels)

Energy intensity is measured by the quantity of energy required per unit of output or activity, so that using less energy to produce a product reduces the intensity. In this case study, energy intensity is represented by the ratio between the energy consumed in agriculture and for housing and the total hours of human activity used in the agricultural sector and for non working activities (physiological overhead, household chores, leisure and education). The energy inputs considered for the final evaluation are: the use of fertilizers, pesticides, the use of tractors, the electricity use for housing and finally the fuel consumption for private purposes. The following table shows the conversion factors used to evaluate the primary energy (fossil energy) contents per unit of inputs and the final evaluation obtained at the household and village levels. At the household and village levels the machinery use is not taken into consideration since the main agricultural production in Hongxing village is based on manual work instead of the use tractors. On the contrary, the tractors are extensively used in Dongtan Agricultural area, which is based on industrial agricultural methods (see next paragraph for the estimation of the energy intensity indicators regarding scenarios 2 and 3).

Table 39 Conversion factors to assess the energy equivalents of inputs in the agricultural sector

Inputs	Conversion factors
Nitrogen	78.06 (MJ/kg)
Phosphorous	17.39 (MJ/kg)
Pesticides	420 (MJ/kg)
Machinery	10 (MJ/Kg/year)
Fuel	46.2 (MJ/kg)
Electricity	3.6 (MJ/Kw)

Source: Giampietro, 2002

Table 40 Energy consumption in the agricultural sector - Household and village levels

Levels	Nitrogen (MJ /year)	Phosphorus (MJ/year)	Pesticides (MJ /year)	TOT (MJ /year)
Household typologies (n-3)				
C1 - Partially off-farm agriculture	1,685,000	135,000	2,000	1,822,000
C2 - Off-farm industry	0	0	0	0
C3 - Partially off-farm agriculture + others	2,560,000	201,000	5,000	2,766,000
C4 - Partially off-farm others	689,000	51,000	1,000	740,000
C5 - On-farm crops	1,552,000	126,000	1,000	1,679,000
C6 - On-farm livestock	766,000	61,000	1,000	827,000
C7 - Off-farm trade and services	0	0	0	0
C8 - Partially off-farm aquaculture	118,000	9,000	0	127,000
Village level (n)	**7,371,000**	**582,000**	**984,000**	**8,937,000**

Source: own elaboration on data from Hogxing village, Chongming island, China

Table 41 Energy consumption for housing – Household and village levels

Levels	**Fuel (MJ/year)**	**Electricity (MJ /year)**	**TOT (MJ /year)**
Household typologies (n-3)			
C1 - Partially off-farm agriculture	1,100	1,500	2,600
C2 - Off-farm industry	2,800	2,400	5,200
C3 - Partially off-farm agriculture + others	500	1,800	2,300
C4 - Partially off-farm others	0	1,300	1,300
C5 - On-farm crops	200	700	900
C6 - On-farm livestock	0	1,400	1,400
C7 - Off-farm trade and services	4,500	1,500	6,000
C8 - Partially off-farm aquaculture	8,300	2,200	10,500
Village level (n)	**174,600**	**179,400**	**353,900**

Source: own elaboration on data from Hogxing village, Chongming island, China

Table 42 Energy intensity indicator – Household and village levels

Levels	**Agriculture (MJ /year)**	**Housing (MJ /year)**	**Human activity (hours/year)**	**Energy intensity (MJ/hours)**
Household typologies (n-3)				
C1 - Partially off-farm agriculture	1,822,000	2,600	23,888	76.40
C2 - Off-farm industry	0	5,200	19,652	0.27
C3 - Partially off-farm agriculture + others	2,766,000	2,300	17,520	158.02
C4 - Partially off-farm others	740,000	1,300	18,995	39.04
C5 - On-farm crops	1,679,000	900	15,184	110.66
C6 - On-farm livestock	827,000	1,400	20,440	40.53
C7 - Off-farm trade and services	0	6,000	19,942	0.30
C8 - Partially off-farm aquaculture	127,000	10,500	22,380	6.16
Village level (n)	**8,937,000**	**3,539,000**	**20,550,233**	**0.61**

Source: own elaboration on data from Hogxing village, Chongming island, China

4.12 Attribution of the criteria scores: scenarios 2 (agriculture) and 3 (organic agriculture)

Following the same procedure used for the representation of Hongxing village (see paragraph 4.8), figure 40 shows the representation of the system this time characterized by both scenarios 2 and 3.

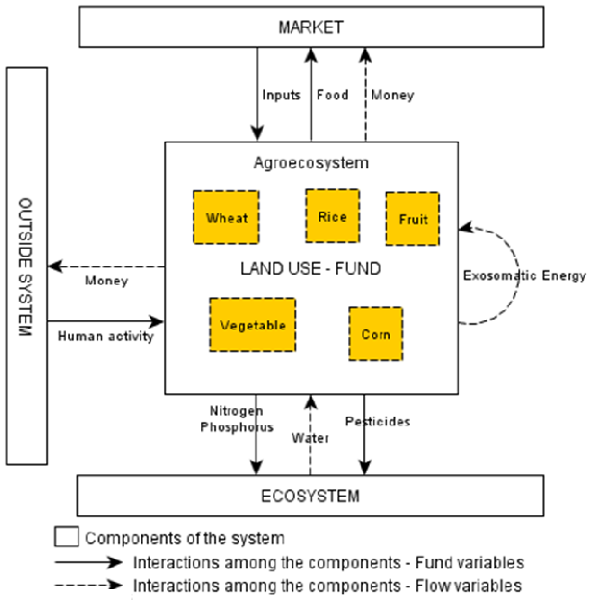


Figure 40 Representation of both scenarios 2 and 3 using fund and flow variables

As we can see from the above figure the new systems, represented by scenarios 2 and 3, are described by means of the same fund and flow variables (human activity, gross income, energy throughput, land use) used in the case of Hongxing village. However, the system represented by the new scenarios differs considerably from the representation in figure 30 (Hongxing village). The complexity of the system in terms of the diversity of the activities performed in the same area reduces significantly: only agriculture is realized in the new scenarios. Moreover, the system depends entirely from the external socio-economic and environmental contexts for its functioning. On the contrary, in the case of Hongxing village the system is partially able to sustain itself in terms of the provision of working hours in the agricultural sector and the resulting production of food.

As it has been explained in paragraph 4.6, the "business as usual scenario" (BAU) relates to the current economic, environmental and social performances of Hongxing village. So, scores of the evaluation criteria refer to the entire village level. While in both scenarios 2 and 3 we assume that the entire land occupied by Hongxing village is converted in agricultural land (this assumption is based on the "rural-urban migration" strategy and the realization of agricultural areas called for by Chongming Master Plan). Then, the difference in the scores of the evaluation criteria between scenarios 2 and 3 is due to the type of agriculture performed on the land, i.e. conventional versus organic agriculture respectively.

Table 43 Organic agriculture performances in Dongtan area. Percentage values with respect to conventional agriculture

Revenues	Costs of production	Hours of work	Use of pesticides	Use of phosphorus	Use of nitrogen
+60	+20	+10	-30	-40	-30

Source: Agroinnova eco-agricultural project (Sino-Italian Cooperation project, 2008)

Table 44 Evaluation criteria scores for scenarios 2 and 3

Evaluation criteria	Scenario (2) (agriculture)	Scenario (3) (eco-agriculture)
Labor productivity (RMB/hour)	45	67
Gross income (Thous.RMB/year)	6,348	10,156
Diversification of risk (%) (qualitative)	very low	very low
Energy intensity (MJ/hr)	518.15	447.02
Use of pesticides (kg ha^{-1} $year^{-1}$)	7.80	5.46
Nitrogen use (kg ha^{-1} $year^{-1}$)	291	204
Food self-sufficiency (%)	0	0
Quality of life (%)	-	-

Source: own elaboration on data from Dongtan Agricultural area and Agroinnova eco-agricultural project

As we can see from table 44, the value attached to the food self-sufficiency indicator equals zero. This is due to the fact that in both scenarios 2 and 3 all the production is sold to the market. The "quality of life" indicator has not been evaluated in this case since the hours of human activity that enter the system are only working hours. Then the "diversification of risk" is very low since the only activity performed is agriculture.

The criteria have been evaluated based on the average values per hectare related to the economic and environmental performances of Dongtan agricultural area in 2008 and indicated in tables 45 and 46 (conventional agriculture) and the performances of organic practices, with respect to conventional agriculture, indicated in table 43. The final evaluation (table 44) has been obtained extending the average values per hectare to the total land of Hongxing village[37].

The evaluation of the energy intensity has been based on information related to the type, weight and horse power of the tractors and the fertilizer and pesticides used in Dongtan agricultural area. The latter information has been subsequently converted in energy content by means of the conversion factors illustrated in table 39.

Table 45 Technical coefficients - Dongtan Agricultural area

Type of crops	Yield (kg/ha/year)	Pesticides (kg/ha/year)	Nitrogen (kg/ha/year)	Phosphorus (kg/ha/year)
Fruits	29,999	9	300	127
Vegetables	14,999	7	300	127
Wheat	6,000	4	270	82
Paddy	7,875	12	315	82
Corn	10,499	6	270	82

Source: data from Dongtan Agricultural area, 2008

Table 46 Economic information – Dongtan Agricultural area

Type of crops	Market price (avg.RMB/kg)	Prod. cost (RMB/ha)	Labor cost (RMB/ha)	Hours of labor (hr/ha/year)
Fruits	2.4	8,250	8,250	1,650
Vegetables	2.5	7,650	6,750	1,350
Wheat	1.7	6,375	570	142
Paddy	2.0	7,545	1,425	360
Corn	1.3	5,790	3,750	930

Source: data from Dongtan Agricultural area, 2008

[37] The use of Dongtan agricultural area average values per hectare applied to Hongxing village land is based on the assumption that there are not significant economies of scale moving from a big farm size, such as Dongtan, to a smaller land extension such as Hongxing village. This assumption is based on strong evidence in literature demonstrating constant economies of scale in agricultural production or even the inverse relationship between farm size and productivity (Sen, 1962; Berry and Cline, 1979; Townsend et al., 1998; Boussard, 1976; Songqing et al., 2005; Kislev and Peterson, 1991). Moreover the extension of Hongxing village (431 ha) is sufficiently large to assume the presence of constant economies of scales.

Table 47 Energy consumption of the agricultural sector in MJ per year

Levels	Nitrogen (MJ/year)	Phosphorus (MJ /year)	Pesticides (MJ /year)	Machinery[38] (MJ /year)	TOT (MJ /year)
Scenario 2 (agriculture)	9,789,874	749,509	1,411,956	59,816,450	71,767,789
Scenario 3 (eco-agriculture)	6,852,912	449,705	988,369	59,816,450	68,107,436

Source: own elaboration on data from Dongtan Agricultural area and Agroinnova eco-agricultural project, 2008

Table 48 Energy intensity indicator – scenarios 2 and 3

Levels	Energy consumption (MJ/year)	Human activity (hours/year)	Energy intensity (MJ/hours)
Scenario 2 (agriculture)	71,767,789	138,509	518.15
Scenario 3 (eco-agriculture)	68,107,436	152,360	447.02

Source: own elaboration on data from Dongtan Agricultural area and Agroinnova eco-agricultural project, 2008

Next sections show how the multidimensional indicators of performance calculated for each scenario can be used to analyze the performances of the two systems represented by figures 30 (Hongxing village – BAU scenario) and 40 (scenarios 2 and 3).

4.13 Construction of the impact matrices

Once the indicators have been evaluated across scales, the next step that characterizes a multi-criteria analysis is the construction of the impact matrix, in which the alternatives to be analyzed, the evaluation criteria and criteria scores are all represented (see chapter 2 for a detailed description of the MCDA methodology). The definition of the development scenarios has been based on the analysis of the main interventions called for by rural development policies in the study area (see paragraph 4.6 for a detailed description of the scenarios). Since the final aim of the entire research is to analyze the coherence of development policies objectives and the trade-offs between the economic, environmental and social dimensions related to the realization of the scenarios across scales (in particular at the household and village levels), two different impact matrices have been considered.

[38] The estimation of the energy requirement for the machinery use takes into consideration the energy equivalent of the fuel consumption which according to Giampietro, 2002 accounts for 3 tons per hectare per year per piece of machinery (in this case due to the type of machineries used in Dongtan and the total weight of all the machineries, a little more than 6 tons, I considered just one piece of machinery), together with the energy equivalent of machinery, which according to the same source of information accounts for 10 MJ/kg/year.

One relates to the household level, in which the different household typologies and the relative performances, i.e. indicator scores, in relation to the evaluation criteria are presented. In this case the consequences on households of the realization of scenarios 2 and 3 result the same. Both scenarios in fact refer to the realization of the "concentration plan", which is the concentration of rural villages in new towns and therefore the "urbanization" of the rural population. To analyze the consequences of the mentioned intervention and its coherence with the development policies goals across scales a comparative analysis of the performances of three aggregate groups of households, represented by: off-farm, on-farm and partially off-farm typologies has been performed. These groups have been obtained by a further aggregation of the household typologies derived by the AHC presented in paragraph 4.7[39].

Table 49 Impact matrix – household level

N.	Evaluation criteria	Unit of measurement	Preferred direction	Off-farm	On-farm	Partially off-farm	Partially off-farm aquaculture
1	Labor productivity	RMB/hour	Max (↑)	6.2	3.4	4.3	7.7
2	Net income	RMB/year	Max (↑)	21,155	5,909	8,827	29,516
3	Diversification of risk	qualitative	Max (↑)	very low	very low	very high	very high
4	Energy intensity	MJ/hour	Min (↓)	0.28	75.60	91.15	6.16
5	Use of pesticides	kg ha^{-1} $year^{-1}$	Min (↓)	0	2.9	4.1	3.4
6	Nitrogen use	kg ha^{-1} $year^{-1}$	Min (↓)	0	118.5	166.7	122.0
7	Food self-sufficiency	%	Max (↑)	0	92	89	89
8	Quality of life	%	Max (↑)	22	26	26	26

Source: data from Hongxing village, 2008

In particular, looking at the characteristics of the 8 clusters and based on their main working activities it has been possible to aggregate cluster C2 with C7 (off-farm typologies), C1 with C3 and C4 (partially off-farm typologies), C5 with C6 (on-farm typologies). Cluster C8, which represents the only case with the realization of aquaculture activity (partially off-farm with aquaculture) has been taken into consideration

[39] Following this procedure it has been possible to maintain the information at a very detailed level, given by the 8 household typologies and at the same time, based on the final aggregation, to present the information in a most readable way.

independently. So, at the household level, the impact matrix shows the four households typologies and their performances (average values of the performances obtained by each household typology when considered separately) in relation to the evaluation criteria.

Table 49 shows the multidimensional performances of the four household typologies in relation to the evaluation criteria chosen in the analysis. The "preferred direction" column represents the objective of the development policy goals in relation to the evaluation criteria considered, i.e. if they aim to maximize or minimize the criterion.

Table 50 Impact matrix - Hongxing village level (BAU), scenarios (2) and (3)

N.	Evaluation criteria	Unit of measurement	Preferred direction	BAU (Hongxing village)	Scenario (2) (agriculture)	Scenario (3) (eco-agriculture)
1	Labor productivity	RMB/hour	Max (↑)	5.05	45	67
2	Gross income	t.RMB/year	Max (↑)	24,528	6,348	10,156
3	Diversification of risk	% (qualitative)	Max (↑)	high	very low	very low
4	Energy intensity	MJ/hour	Min (↓)	0.61	518.15	447.02
5	Use of pesticides	kg ha^{-1} $year^{-1}$	Min (↓)	7.03	7.80	5.46
6	Nitrogen use	kg ha^{-1} $year^{-1}$	Min (↓)	283.55	291.00	203.69
7	Food self-sufficiency	%	Max (↑)	76	0	0
8	Quality of life	%	Max (↑)	25	-	-

Source: data from Hongxing village, Dongtan agricultural park and Agroinnova eco-agricultural project

Table 50 shows the performances of the different scenarios analyzed in relation to the evaluation criteria chosen. The only difference with the previous analysis is that at this aggregate level, instead of the "net income" indicator, we used the "gross income" which represents the total monetary flow produced by the different scenarios.

4.14 Analysis of the results

This section presents the results achieved at different hierarchical levels, that of households' typologies, that of Hongxing village and that of the three scenarios of development. Based on these findings it is also discussed the effectiveness of rural development policies interventions at the local scale: village and household.

4.14.1 Main results at the household level

This section illustrates the results obtained at the household level based on the three main household typologies identified: off-farm, on-farm and partially off-farm. For that purpose, results of table 50 are illustrated by means of a radar diagram.

In particular, table 50 shows the multidimensional indicators' scores with regard to the households' typologies obtained by the application of the clustering procedure. The multidimensional indicators considered in the analysis have been selected based on the main goals of the development policies interventions in Hongxing village as it has been explained in paragraph 4.5. The various criteria can also be seen as representatives of legitimate contrasting strategies of different rural households, for instance the maximization of the income (off-farm typologies) or the maximization of food security (on-farm and partially off-farm typologies).

In relation to these distinct strategies rural households reveal also different socio-economic and environmental performances. In figure 41 a synthesized representation in a multi-criteria performance space[40] of the above households' strategies is presented. This synthesized representation shows that households involved in agricultural activities, such as on-farm and partially off-farm households perform better than off-farm typologies in terms of the social dimension especially for what concerns "quality of life" and "food self-sufficiency" criteria. On the contrary off-farm typologies reveal good environmental and economic performances. At the same time, off-farm jobs reveal an economic productivity of labor higher than on-farm activities, which makes the difference in the economic performance of off-farm households in comparisons to the other household typologies analyzed. Then, looking at the performances of the various households typologies, we can easily recognize that the household typology classified as "partially off-farm with aquaculture", and characterized by an important rural vocation, shows for the majority of the indicators a better performance than the others.

[40] For the radar diagram representations of figures 41 and 42 the following normalization procedure of the indicators' scores displayed in table 49 has been used: (x-min)/ (max-min)*100. Where, min and max are respectively the maximum and minimum values of the indicator scores and x the starting value to be normalized. Then, for establishing the direction of the indicator (maximizing or minimizing) the following equation has been used for the indicators to be minimized with respect to the optimum (in this case pesticides use, nitrogen use in agriculture and energy intensity): -[(x-min)/ (max-min)*100]+100. With the above normalization procedure all the indicators assume values that go from 0 to 100, where 0 represents the worst situation and 100 the optimum one with respect to the minimum and maximum values assumed by the indicators themselves. This means that a household typology that performs better with respect to a criterion, reaching the optimum doesn't represent the optimum in absolute terms but always in relation to the performance of the other typologies.

These results are particularly useful to analyze at this point the impacts and coherence among the objectives and the interventions of the Chongming master plan development policy at the household level. In particular, the "urbanization" of rural people[41] entailed by Chongming Master Plan, will result in the following main impacts at the household level:

1) Reduction of the diversity in terms of household typologies;
2) Reduction of the social performance of household in terms of food self-sufficiency, diversification of risk and quality of life;
3) Improvement of the economic performance of household in terms of net income and labor productivity;
4) Reduction of the environmental impacts of household especially on the soil resource.

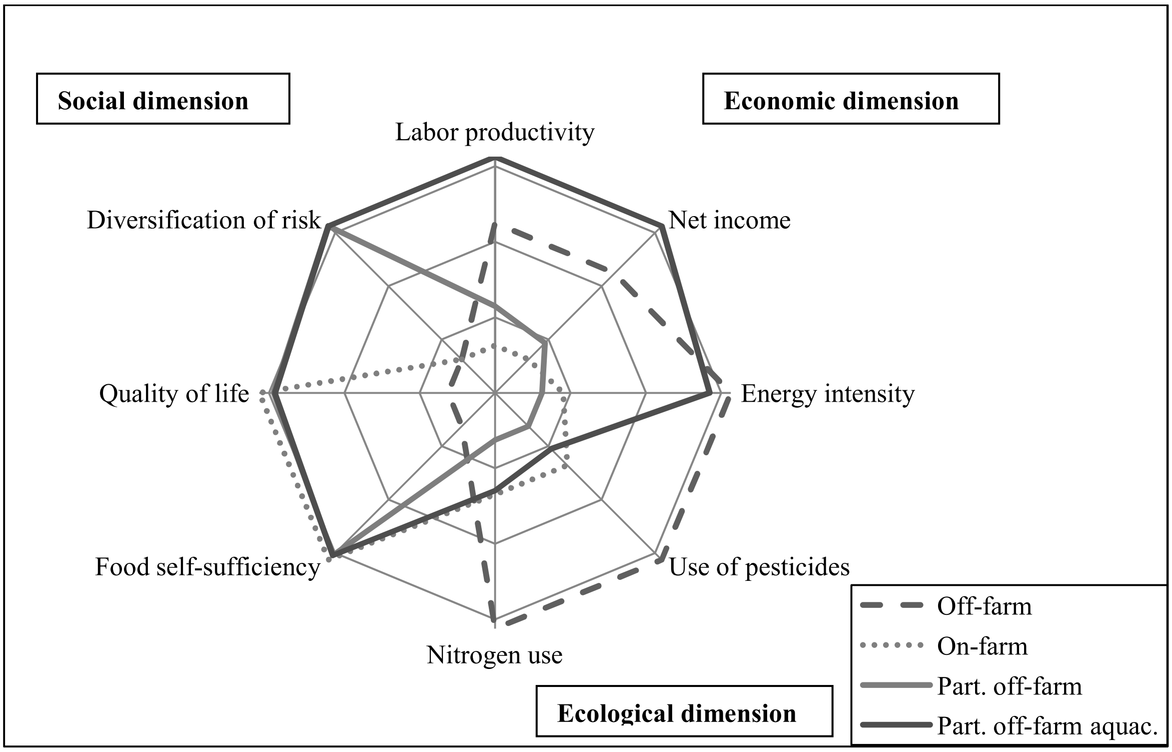


Figure 41 Economic, ecological and social performances of different household typologies

So, even though on the economic and environmental points of view off-farm households perform better than the households directly involved in the agricultural sector, they result

41 The urbanization of rural people and the related impacts at the household level has been analyzed based on the comparison of the environmental, economic and social performances of off-farm typologies with respect to the performances of on-farm and partially off-farm typologies showed in table 50.

more dependent to external markets for both food and work provisions. Off-farm typologies are in fact dependent to the availability of off-farm jobs from the labor market. At the same time, the process of urbanization of rural people is linked to a loss of household typologies based on traditional agricultural practices actually present in Chongming island. Moreover, in relation to the coherence between the development policies goals (see table 20) and the local interventions, one can conclude that, the new plan does not satisfy the food security goal at least at the household level. Off-farm households are in fact completely dependent to the external markets in term of food provisioning.

4.14.2 Main results considering the three scenarios of development

Scaling up from household to the village level it is possible now to analyze the consequences of the rural development policies interventions looking at the three scenarios (figure 42).

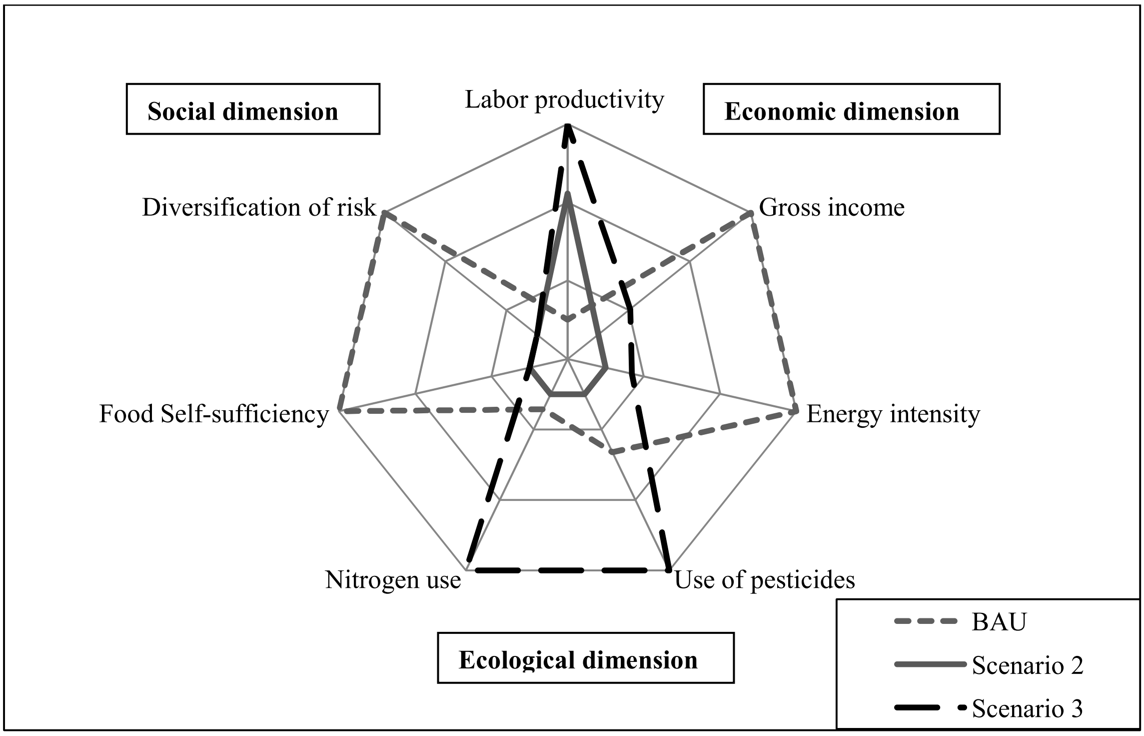


Figure 42 Economic, ecological and social performances of different scenarios

In the previous figure, the business as usual (BAU) scenario performs better than scenario 2 (conventional agriculture) in terms of environmental, social performances and the total production of gross income, while with respect to the labor productivity scenarios 2 and 3 show better results.

Consequently, with scenario 2 only one of the objectives of the rural development policy goals across scales is achieved, that is to increase the labor productivity of the area, but resulting in bad environmental and social performances. On the other hand, scenario 3 guarantees a better performance from an environmental point of view related to the use of fertilizers and pesticides but it shows worst results in terms of energy intensity. Moreover, the social performance declines, as well as in the case of scenario 2. As a result, with the implementation of scenario 3 only the RDP objectives related to the protection of the environment and natural resources are achieved, together with the increase of the labor productivity.

Summarizing, in both scenarios 2 (conventional agriculture) and 3 (eco-agriculture) there are trade-offs between the environmental, economic and social dimensions. In particular, moving from BAU to scenario 2, the improvement of the labor productivity of the system results in a reduction of the environmental and social performances. At the same time, moving from BAU to scenario 3, the improvement of the environmental quality in terms of the use of fertilizers and pesticides together with the increase of the labor productivity results in a reduction of the social performances. As a consequence, the social dimension is always penalized by the two new scenarios. In particular, “food self-sufficiency” and “diversification of risk” in both the new alternatives show a worst result with respect to the BAU scenario.

Based on the above considerations, the following conclusions can be drawn:

1) The implementation of scenarios 2 and 3 results in a decline of the social performance of the area under investigation;
2) The complexity, in terms of the diversity of the elements composing the area under investigation, reduces moving from BAU to both scenarios 2 and 3, i.e. the diversity of household typologies decreases;
3) There are always trade-offs between different objectives, and none of the scenarios satisfy simultaneously the development policies goals across scales, i.e. there is no coherence between the RDP goals and the policy interventions.

4.15 Comparison of the scenarios based on the representation of the "socioeconomic" and "biophysical" dimensions. Indicators versus absolute values

This section shows a comparison of the systems represented by BAU scenario with both scenarios 2 (conventional agriculture) and 3 (eco-agriculture) based on a parallel representation of the socioeconomic and biophysical aspects. The analysis follows the multi-scale integrated approach and it is based on the simultaneous representation of the following variables: human time, land use, energy throughput, and gross income for the BAU, scenario 2 and scenario 3. The analysis this time focuses on the economic, environmental and social performances of different patterns of agriculture associated to the scenarios, based on the analysis of the absolute values.

Summarizing, the three scenarios have the following characteristics:

- Low external power agriculture (LEPA) or traditional agriculture. This classification refers to the BAU scenario, in which the realization of agriculture is based on manual work from farmers instead of the use of tractors. Moreover, the system analyzed in this case is composed by the rural community (i.e. inhabitants), the village and the agro-ecosystem (see figure 30). As a consequence the activities performed in the system refer not just to agriculture but also to industry, trade and services and non working activities, such as leisure and education and physiological overhead. This system is also characterized by the fact that some of the flows (i.e. monetary flows) and products (i.e. agricultural production for the local consumption of food by the population of rural communities) generated remain in part within the system to support its functioning (for a visualization of this aspect of the system see again figure 30 and figure 40);
- High external power agriculture (HEPA) or industrial agriculture. This classification refers to both scenarios 2 and 3, in which the realization of agriculture is based on the use of tractors. Then the two scenarios differ between them based on the type of agricultural practices performed, i.e. conventional versus organic agriculture. Moreover, the corresponding system is characterized by the presence of the agro-ecosystem only (see figure 40). In this case the natural pattern of reproduction of rural communities doesn't exist since rural dwellers are supposed to move to the cities (i.e. the rural-urban migration plan). In this system

all the flows (the monetary flows managed by big enterprises, which in this case are the owners of the land) and products (the agricultural production, mostly sold to cities' markets to feed urban population) generated leave the system.

The comparison of the above mentioned scenarios in metabolic terms sheds some light on the elements that characterize the different level of complexity of the two resulting systems and on the related economic, environmental and social aspects.

In addition, the analysis shows the different multidimensional impacts related to land use changes based on the analysis of the metabolism of the three scenarios.

The comparison is showed by means of the four angles diagram, already used in the multi-scale representation of the labor productivity criteria illustrated in paragraph 4.11.2.

Therefore, using the concept of multi-level matrices it has been possible to represent the indicators LP, energy intensity and food self-sufficiency for each scenario, using the variables human time (fund), gross income (flow) and land use (fund). This representation makes possible to focus the analysis on the sustainability of the different scenarios taking into account, in addition to the indicators presented by the use of the impact matrix, the performances of the scenarios in terms of absolute values (extensive variables, i.e. total gross income and total energy produced or consumed by the scenarios).

To do that, three different graphs are used. The first one (figure 43) illustrates the economic dimension by means of the simultaneous representation of the variables human time and gross income. The axes represent the extensive variables: hours of human activity in the paid work sector and for subsistence and the resulting gross income generated, including also the "virtual income". While, the angles (δ, γ, β, and α) represent the intensive variables, i.e. the ratios between extensive variables. Therefore, the angle δ in the upper-right quadrant of the graphic in figure 43 refers to the labor productivity of the systems (BAU, scenarios 2 and 3), given by the ratio between the total gross income and the total human activity expressed in hours. In other words, the gross income generated by the scenarios per hour of human activity. The angle γ in the lower-right quadrant depends on the fraction of GI generated by the paid work sector. Similarly, the angle α in the upper-right quadrant depends on the fraction of human activity dedicated to the paid work sector. Finally the angle β in the lower-left quadrant indicates the labor productivity of the paid work sector at the level n-1.

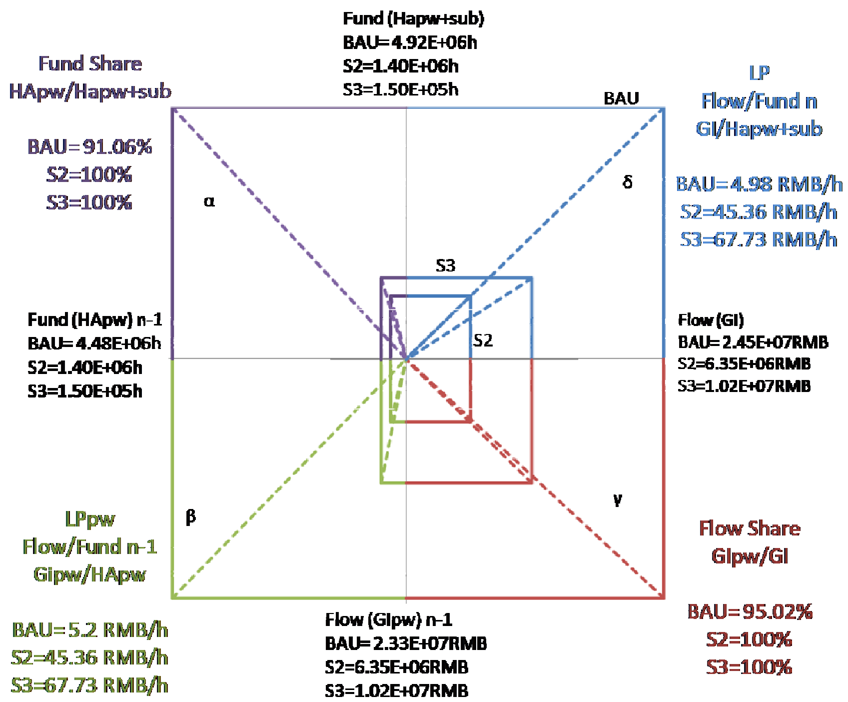


Figure 43 Representation of the economic performance of the systems under investigation in terms of productivity per hour of labor (LP). BAU scenario versus Scenario 2 and Scenario 3

From the above representation two main aspects of the different scenarios can be analyzed:

1) the performance of the systems based on the analysis of the extensive variables, i.e. "what the systems are" in terms of their size expressed by the hours of human activity and the total monetary flow;
2) the performance of the systems based on the ratio between extensive variables (i.e. intensive variables, Flow/Fund), i.e. "what the systems do" in terms of economic productivity expressed by the indicator LP (GI/HA).

Therefore, if one looks at the performance of the scenarios based on the analysis of the extensive variables, it results that the size of the BAU scenario in terms of hours of human activity and the corresponding gross income produced is bigger that scenarios 2 and 3. The BAU scenario results 35 and 32 times bigger than scenarios 2 and 3, respectively, in terms of hours of labor and approximately 4 and 2 times bigger in terms of the gross income produced. On the other hand, if one looks at the labor productivity of the systems, i.e. the gross income produced per hour of work, scenario 2 results 9 times more productive, while scenario 3 is 13 times more productive than BAU scenario. *As a result, the new scenarios produce less wealth and are characterized by less hours of human activity in absolute terms, although they are more efficient in terms of labor productivity.*

Let's now analyze the consequences of the increment in the economic efficiency of the system moving from BAU to scenario 2, considering at this time the environmental and social dimensions (figures 44 and 45 respectively).

The environmental dimension is analyzed based on the consumption of energy in absolute terms (extensive variable) and looking at the energy intensity indicator (ratio between energy consumption per hours of work, i.e. intensive variable). So, the axes of the new graph represent the hours of human activity in the agricultural sector and the private sector and the equivalent energy consumed. In the case of scenarios 2 and 3, since the only activity realized is agriculture and the community is not represented the only energy consumed refers to the agricultural sector. Therefore, the extensive variables represented in the graph are: the total human activity (THA), the total energy throughput (TET), the human activity in the agricultural sector (HAagr) and finally the energy throughput of the agricultural sector (ETagr). While, the intensive variables are the ratios between the extensive variables described above (ET/HA) and relate to the energy intensity indicator (also called exosomatic metabolic rate, EMR). In this case, thanks to the multi-scale representation of the variables, one can realize the analysis at two levels: the whole system (village versus only agricultural area) level (n) and the agricultural sector, level (n-1).

Therefore, if one looks at the performance of the scenarios based on the analysis of the extensive variables, it results that the "size" of the BAU scenario in terms of hours of human activity is bigger that scenarios 2 and 3, although it results smaller in terms of energy throughput at level n. The BAU scenario results 167 and 156 times bigger that scenarios 2 and 3 respectively in terms of hours of human activity (this big difference depends on the fact that the human activity in the BAU scenario accounts also for the time spent in personal care and household chores) and 5.7 and 5.4 times smaller in terms of energy throughput. On the other hand, if one looks only at the agricultural sector, the BAU scenario results 11 times bigger than scenarios 2 and 3 in terms of hours of human activity and approximately 8 times smaller in terms of energy throughput. Moreover, in terms of energy intensity (i.e. energy throughput per hours of human activity), scenarios 2 and 3 results 103 and 90 times less efficient respectively looking at the whole system and 94 and 83 times less efficient respectively looking at the agricultural sector only.

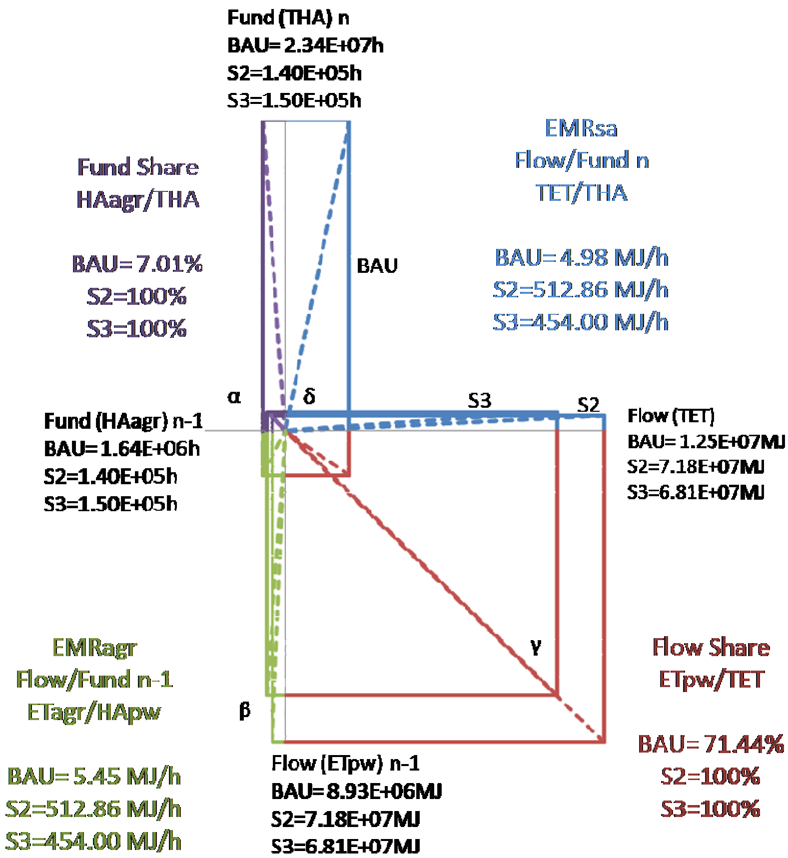


Figure 44 Representation of the environmental performance of the systems under investigation in terms of energy intensity per hours of human activity (i.e. Exosomatic Metabolic Rate- EMR). BAU scenario versus Scenario 2 and Scenario 3

As a result, the new scenarios consume more fossil energy as a whole and are characterized by less hours of human activity in absolute terms. As a consequence, they result less efficient in terms of energy intensity.

Finally, in graph 45 the social dimension is analyzed in terms of the food self-sufficiency of the scenarios. The extensive variables used are the following: gross income and hectares of land related to the agricultural sector. The level of food self-sufficiency of the scenarios has been analyzed by means of the fraction of the agricultural land (LIAP) used for subsistence purposes (LIP sub). At the same time, the graph shows the fraction of the agricultural gross income derived from the realization of subsistence agriculture (GI sub), i.e. the "virtual income" (for a detailed explanation of the method used to evaluate the virtual income see paragraph 4.5).

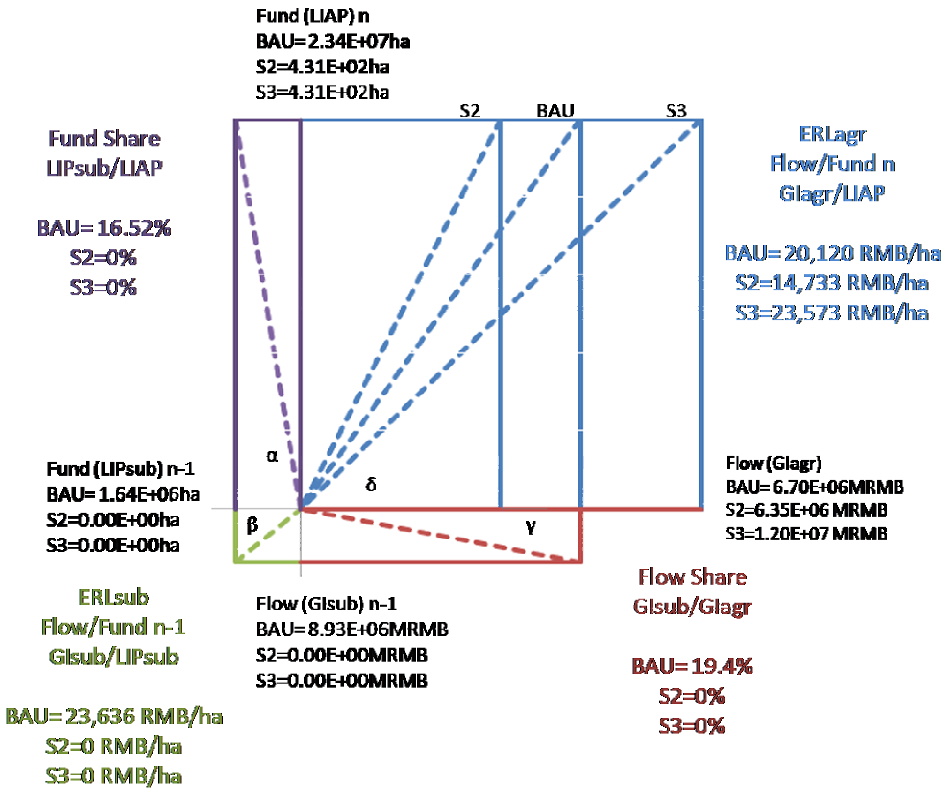


Figure 45 Representation of the social performance of the systems under investigation in terms of food self-sufficiency and Economic Return on Land (ERL). BAU scenario versus Scenario 2 and Scenario 3

Therefore, if one looks at the performance of the scenarios based on the analysis of the extensive variables, it results that in the case of BAU scenario the 17% of the total land in agricultural production is used for subsistence purposes. In monetary terms, this fraction amounts for the 19% of the total gross income generated by the agricultural sector. Instead, in the case of scenarios 2 and 3 the land is entirely used for agricultural production, i.e. the fraction of the land used for subsistence purposes amounts for the 0%.

As a consequence, in both scenarios 2 and 3 all the agricultural products leave the systems and therefore they result completely dependent to the external market for their functioning (in terms of inputs, including the labor force). On the contrary BAU scenario has the capacity to sustain itself in terms of food production (the 76% of the food consumed in Hongxing village is self-produced) and also in terms of labor. In addition looking at the economic return of the land (ERL) given by the fraction between the gross income from agriculture and the land used for agricultural purposes , it results that the performance of the BAU scenario is worst with respect to scenario 3 but better than scenario 2.

Summarizing, the analysis presented until now allowed investigating the different scenarios, and therefore the land-use change, based on the economic and environmental efficiency and at the same time to investigate their food self-sufficiency in terms of the dependency to the external contexts.

On the basis of the results obtained and in relation to the realization of the scenarios 2 and 3, the following conclusions can be drawn:

1) Scenarios 2 and 3 compared to the BAU scenario result less efficient in terms of energy intensity but more efficient with respect to the economic dimension (i.e. labor productivity), even though they produce less gross income in absolute terms and they are characterized by less hours of human activity (figures 46 and 47);
2) Scenarios 2 and 3 are completely dependent to external markets (in terms of inputs) for its functioning (figure 48).

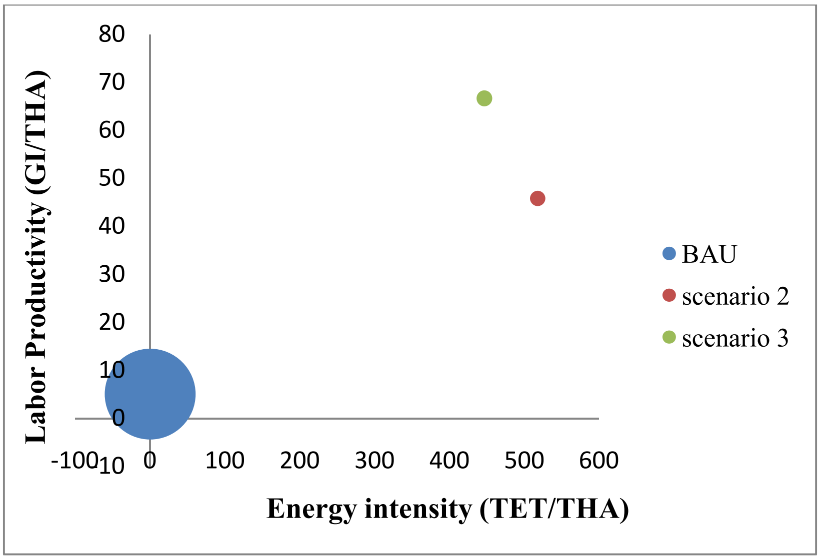


Figure 46 Economic versus environmental aspects related to the different scenarios. Energy Intensity versus Labor Productivity (LP). Bubble's size = Total Human Activity in paid work + subsistence (THA pw + sub)

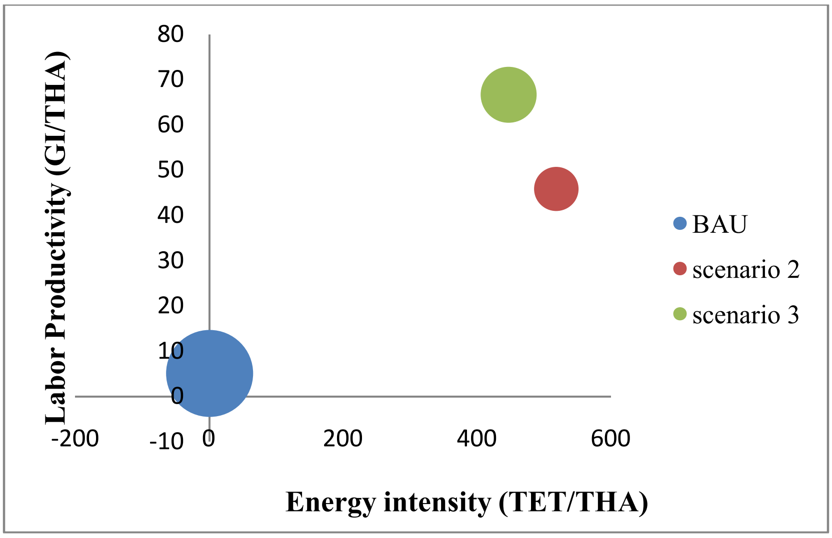


Figura 47 Economic versus environmental performances related to the different scenarios. Energy Intensity versus Labor Productivity (LP). Bubble's size = Total Gross Income produced by the paid work sector + virtual income (GIpw+sub)

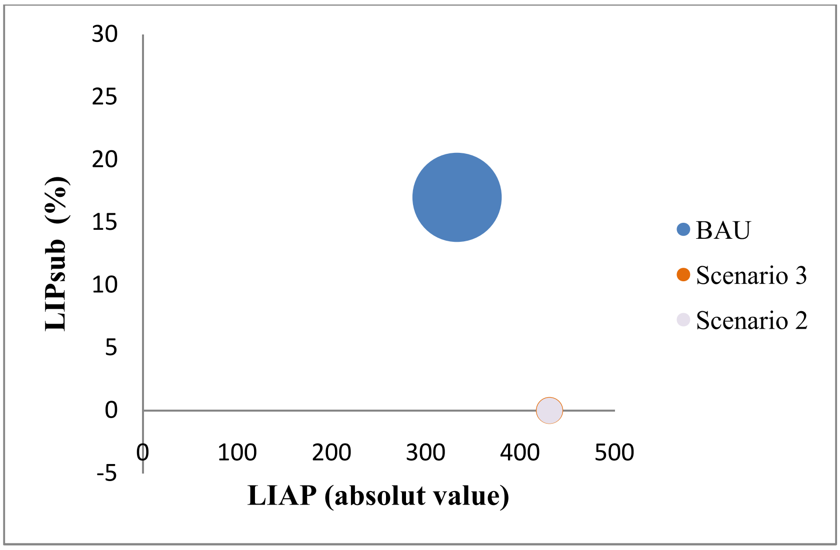


Figure 48 Performance of the scenarios in terms of self-sufficiency. Land in production for subsistence (LIPsub) versus land in agricultural production (LIAP). Bubble's size = Total Human Activity in agriculture (THA agr)

4.16 Differences in density of energy and monetary flows generated by different land uses

This section compares the capitalization of the agricultural sector in terms of energy and monetary flows for the different patterns of agricultural land use. These patterns are related to the scenarios defined in the previous paragraph and comprising also a new scenario (for an explanation of the characteristics of the scenarios see the previous paragraph): (i) Low external power agriculture (LEPA), which corresponds to the BAU scenario; (ii) High external power agriculture (HEPA) based on conventional cultivation practices, which corresponds to scenario 2; (iii) High external power agriculture (HEPA) based on organic cultivation practices, which corresponds to scenario 3; and finally (iii) subsistence agriculture. The latter system relates to the production of food to sustain the food requirement of the rural communities. It is based on traditional agricultural production.

Looking at the performance of the agricultural systems listed above, in terms of density of both cash and energy flows per worker and per hour of work (figures 49 and 50), we realize that the high level of capitalization of the HEPA systems in comparison to LEPA and subsistence systems bring us to two critical aspects: its neglected social and environmental dimensions.

From a social point of view high-power agricultural systems lead to a dramatic reduction of the requirement of human labor (this aspect is showed in figure 49, in which the size of the bubbles indicates the requirement of hours of work of the different patterns of agricultural land use considered). As a consequence, rural people are forced to leave their traditional working activities and to change their way of living moving from rural to urban areas (i.e. urbanization of the rural population). Moreover, from an environmental point of view high-power agricultural systems result less efficient. According to figure 50, the energy flow in terms of fossil energy used per worker and per hour of labor is much higher in high-power agricultural systems (scenarios 2 and 3) than in traditional systems (BAU and subsistence).

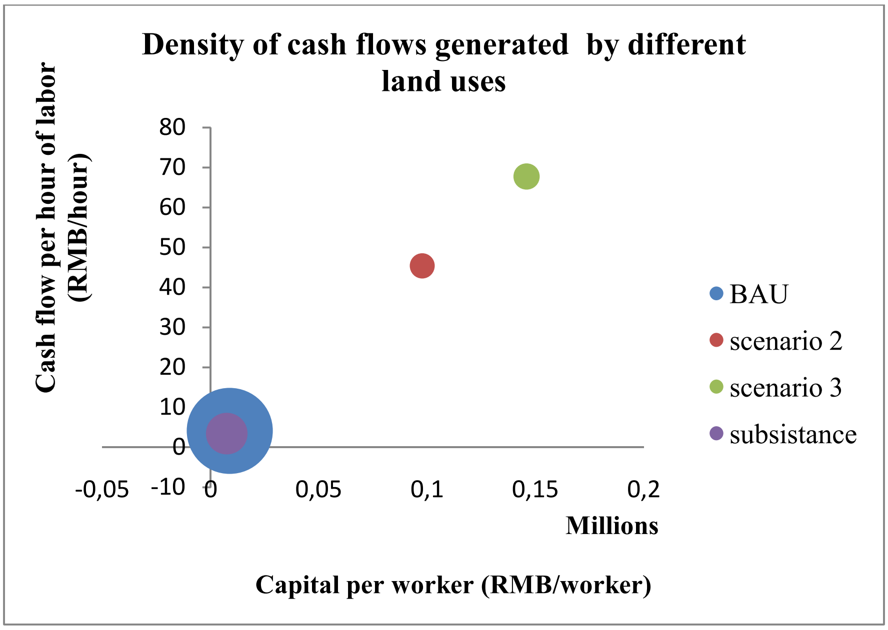


Figure 49 The density of monetary flows related to different typologies of land uses. Bubble's size = total human activity in the agricultural sector

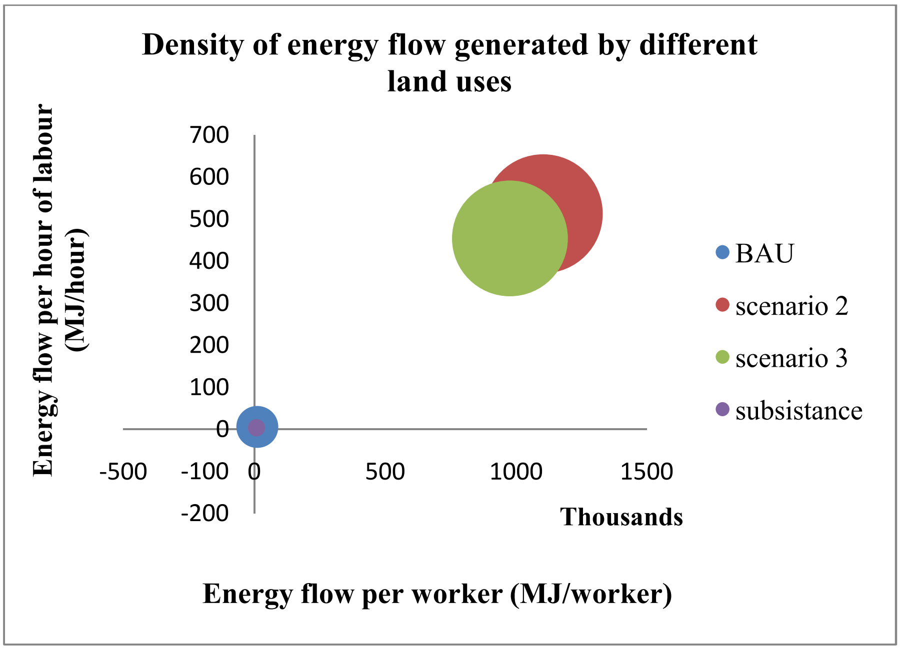


Figure 50 The density of energy flows related to different typologies of land uses. Bubble's size = total energy flow in the agricultural sector

From the above results it is clear that, the adoption of urbanization strategies together with the creation of HEPA patterns implies the abandonment of integrated rural realities in favor of simplified agricultural systems. These systems are characterized by the presence of few relevant inputs (those that have to be used in the process of agricultural production) and few relevant outputs (food products), useful for the maximization of the profits. In this paradigm, agriculture is no longer functional for the reproduction of the funds corresponding to the rural community; instead it focuses on how to optimize the generation of flows (mainly monetary flows) (Giampietro and Mayumi, 2009). Based on the results obtained, the consequences of the implementation of this paradigm can be summarized as follows:

- a deterioration of the environment (in terms of fossil energy consumed);
- a decline of the social aspects (the loss of the historical identity and heterogeneity of rural areas together with the loss of food security and diversification of risk of rural people);
- an increase of the economic performance (i.e. of the monetary flows per worker and per hour of labor).

In other words, the implementation of urbanization strategies together with HEPA practices is able to increase the economic capitalization of rural systems but at the expense of the environmental and social aspects. If the priority of development strategies in rural areas is to increase rural development, the paradigm described above does not seem to be the best policy option. Instead, the multifuctionality of rural communities based on an integrated set of activities should be taken into consideration in decision-making as a viable alternative for the achievement of the rural development goals (for a more detailed discussion and policy recommendations related to this issue see the next paragraph).

4.17 Discussion

As pointed out in the introduction, the main objective of this part of the thesis has been to analyze the possible effects of rural development policies at various hierarchical levels with a particular focus on local communities and rural households. To achieve this objective, an integrated approach characterized by the combination of various methodologies has been used. In particular, concepts coming from ecology, complex system theory and thermodynamics have been used for the characterization of the area under investigation. It has been assumed that socioeconomic systems, such as households and Hongxing village are complex adaptive systems organized in hierarchical levels. This approach required the use of appropriate methodologies for a full understanding of the functioning of the mentioned systems. The main methodologies utilized here have been two. Firstly, the multi-criteria analysis has been used for the definition of the scenarios and identification of the evaluation criteria based on the previous analysis of the RDP goals. Secondly, the MuSIASEM approach (Giampietro, 2003), based on the fund-flow model (Georgescu-Roegen, 1975) has been applied. The latter allows for the representation of the area under investigation by means of a multi-scale representation. The idea behind the present work comes from the presumption that an integrated approach better deals with the fundamental characteristic of the current development policies, which is to find a compromise solution between non-equivalent goals afferent to different dimensions of analysis. If one looks at the goals of the Chinese National Government of modernizing the agricultural sector, one recognizes immediately the above mentioned characteristic. The national policies in fact deal at once with the following goals (11^{th} Five-Year Plan for National Economy and Social Development of China):

1) Food security;
2) Environment protection;
3) Economic development;
4) Good management of natural resources.

In other words, they call for the achievement of sustainability. The same can be said for the Chongming island development policies. What I tried to understand here is whether these policies could achieve sustainability, and in particular what are the consequences of those interventions at the level of local communities and rural households.

For this purpose I analyzed one of the main interventions of the Chongming master plan, which is the most representative of the entire plan and related to rural villages: the increasing of the non-agricultural population (i.e. the urbanization strategy). The plan aims at the concentration of rural villages in new towns and consequently the transformation of a large number of rural households in urban ones (according to the Chongming master plan urban people will increase from the actual number of 157,000 to 500,000 in 2020). As a consequence, the land-use of Hongxing village will change to only agricultural land.

Based on the results presented in section 4.14, the above mentioned interventions don't seem to be effective in terms of the achievement of the RDP goals and in relation to the implementation of sustainability in Hongxing village. Instead, the process of urbanization of households and the land-use change resulting from the application of the development policy interventions will result in a decline of the social and environmental performance in relation to all the alternatives analyzed. Moreover, a wider interpretation of the results consent to suggest that in order to achieve a compromise solution in terms of economic development, natural resources conservation, food security and quality of life of rural households in Hongxing, an effective strategy would try to achieve a balance between off-farm and on-farm activities and not the complete abandonment of residential farming. This strategy, in fact, would permit to rural households to reach satisfactory economic performances and at the same time to guarantee an acceptable level of food security and quality of life, such as the case of households performing aquaculture.

In conclusion, according to the data presented, a strategy based only on the reduction of the rural-urban gap in economic terms cannot be considered sustainable since it results also in bed performances in terms of food self-sufficiency, risk diversification and quality of life.

This strategy doesn't seem to be sustainable if we look also at the recent global economic crisis and at the consequences on rural people of the wider Chinese National Policy. In fact, the process of urbanization of rural people implemented by the central government to sustain economic growth started to show its weaknesses in concomitance with the first signals of the global financial crisis. It has been estimated that from the beginning of 2008 more than 20 million of migrant workers had returned to the countryside from cities without jobs. Some of them are engaged again in farming, while others are still seeking a job (Wang, 2009). This dramatic aspect of the fast development of China demonstrates a failure of the massive abandonment of rural areas and of the rural development policies implemented by the Chinese government in the last years. At the same time, it highlights the importance of a preservation of rural areas' identity based on the achievement of a good balance in the diversification of income generation between farming and non farming activities.

In the light of these findings, the following recommendations should be carefully considered in trying to implement rural development in Chongming island:

1) Seeking for local development and education to provide rural households with the opportunity to reach a good balance between working on-farm and off-farm;
2) Foreseeing the implementation of incentives for the realization of remunerative agricultural activities, such as the case of aquaculture:
3) Foreseeing the development of alternative sources of income for rural households at the local level, such as agroforestry and ecotourism;
4) Guaranteeing a certain level of food self-sufficiency to cope with periods of economic crisis;

5) Improving income stabilization trough the creation of a favorable environment for dynamic diversification of the rural economy.

These objectives could be achieved by an integrated land resource management based on the coexistence of the actual rural reality of Chongming island with the other objectives of the Master Plan, such as the increase in the forest area and the improvement of the tourism sector. In this direction, a diffusion of agroforestry and ecotourism could be a way to create a favorable environment for a dynamic diversification of the rural economy avoiding the rural-urban people transformation and the consequent abandonment of agricultural activities. Agroforestry and ecotourism have also the potential to protect the environment from high intensity agricultural production, based on the massive use of fertilizers and pesticides, which currently represents the most significant source of pollution of the island (Huang et al., 2008). An integrated land resource management based on the combination of cropping, aquaculture, agroforestry and ecotourism managed by local people instead would be a way toward a sustainable development of Hongxing village and in a wider view of Chongming island. At the same time, the adoption of an integrated land use management might result in an increment of food security and income stabilization to guarantee rural households to better deal with periods of economic crisis.

On the other hand, if one looks at the level of the village, the analysis has showed the potential weaknesses of the policy interventions called for by Chongming master plan to achieve sustainability. These can be synthesized in three main points. Firstly, in both interventions the social aspect is always penalized. The performances of the new scenarios in terms of food self-sufficiency and diversification of risk are worst than the current situation (BAU scenario). Secondly, the environmental aspect can be partially improved however only with the realization of organic agriculture (with a reduction in the use of fertilizers and pesticides but not in terms of energy intensity). Thirdly, the land use change in both cases results in a reduction of complexity derived by a decrease of the cultural diversity (i.e. disappearance of traditional agricultural practices and of some typologies of households).

In conclusion, according to the data presented, a strategy based on the reduction of the complexity of the area represented by Hongxing village cannot be considered sustainable. Alternatively, a good rural development policy should try to take into account all the different aspect that characterize socioeconomic systems, seeking for a good balance (compromise solution) among the maximization of the economic, social and environmental dimensions. Moreover, interventions should pay more attention to the impacts they produce at the very local level, analyzing the social aspect not just as a matter of economic development in monetary terms but also including qualitative aspects such as for instance quality of life, diversification of risk and food self-sufficiency.

4.18 Conclusions

This case study has showed how it is possible to realize an integrated approach which takes into account different dimensions of analysis and establishes a bridge across different scales. The conceptual framework and the general operational strategy used for the identification of the indicators representing the various levels of analysis have been based on the following elements: the objectives of the National and Chongming development policies, the most significant human pressures on Chongming natural resources, previous studies, expert judgments and my personal perceptions of the Chongming rural reality derived from the realization of a four months field work. Based on these reflections, the "site-specific" indicators embrace the main issues related to natural resource management in the island and the main political objectives.
By utilizing those indicators, the proposed framework has allowed to:

1) identify the resource use pattern of representative rural households in terms of time, land, energy, and income;
2) identify the socio-economic and biophysical constraints rural households have to face when they are taking decisions regarding the use of different resources;
3) identify different strategies rural households have to face to reach a compromise between alternative goals (food security, maximization of the income, environmental protection);
4) identify the possible trade-offs between income generation, environmental protection, food security, risk diversification and quality of life;
5) achieve an understanding of the factors that characterize rapidly changing and dynamic rural realities, such as the ones represented by Hongxing village and Chongming island;
6) investigate whether the current development policies in Chongming may in fact promote local development and natural resources conservation.

5 CONCLUSIONS

General conclusion

This chapter is dedicated to the presentation of the conclusions related to the entire thesis. In addition, it explains the possible future directions of research that could be undertaken with regard to the case studies that have been presented.

The thesis argues that when analyzing sustainability of Rural Development Policies (RDP), one has to seek ways to understand how the socio-economic and ecological aspects of social systems interweave in coupled social-ecological systems, taking also into consideration their multidimensional characteristics. In other words, one has to deal with the identification of socioeconomic and environmental constraints and characteristics related to the development of coupled social-ecological systems. The design of proper sustainable development interventions in rural areas is always a difficult task because of the multidimensional and multi-scale aspects of rural development goals. These aspects imply the presence of trade-offs between the environmental, economic and social dimensions and therefore the necessity to seek for compromise solutions instead of maximization strategies. Moreover, often times the social dimension is neglected when designing sustainability interventions, due to the challenge of calculating it in quantitative terms. As a consequence, political interventions that seem to be good for the achievement of sustainability are frequently unsustainable if a proper integrated assessment, inclusive of the social aspect, is performed.

Based on the relation between sustainability and RDP, this thesis has provided examples of application of integrated approaches, based on the combination of multi-scale (MuSIASEM) and multi-criteria (SMCE) methodologies, to evaluate whether or not rural development strategies, implemented in recent years are proving to be effective with respect to: (1) their own stated overall objectives and (2) their common stated objective of sustainable development. With respect to these aims, the integrated approaches utilized have been very useful, in both case studies, for the achievement of the following results:

- The identification of site-specific indicators able to represent the performances of coupled social-ecological systems at different scales and dimensions of analysis;
- The identification of trade-offs related to the environmental, social and economic dimensions of RDP;
- The identification of possible constraints related to the implementation of RDP;

- The analysis of the effectiveness of RDP to achieve sustainability according to non-equivalent goals;
- The discussion related to both the present situation and the evaluation of future scenarios of the area under investigation.

The main advantage of the use of integrated approaches is the possibility to analyze social systems through the use of multidimensional indicators represented across scales avoiding the reductionism typical of oversimplified models in which only some of the dimensions of sustainability are taken into account or just one scale considered.

The use of the two methodologies has been demonstrated to be very significant to capture both the multidimensional aspects of Rural Development Policies and to understand the functioning of rural systems in terms of their interactions with the external environmental and economic contexts and across different levels of analysis.

In fact, the MuSIASEM approach makes it possible to describe the human-environment interactions establishing a coherent relation among variables and across scales. This characteristic allows for the representation of the typical hierarchical organization of complex systems. The generation of coherent relations among the various pieces of information improves the robustness of the analysis and the possibility of generating synergism in the parallel use of different disciplines.

The SMCE is a robust approach for the analysis of the multidimensional aspect of sustainability issues to support the decision-making process. Social Multi-Criteria analysis is particularly useful when significant environmental and social impacts need to be included in the analysis, such as the case of rural development policy. Thus, more explicit recognition is given to the fact that a variety of objectives and indicators may influence policy decisions. Based on the above considerations, employing multi-criteria approaches is essential to capture the multidimensional aspects of the policies' objectives.

Obviously, the implementation of MuSIASEM and SMCE provides a way to analyze coupled social-ecological systems that doesn't have the presumption to be comprehensive. On the contrary, the methods utilized are based on the unavoidable simplification of the reality typical of any approach, but trying to include in the analysis as many elements as possible according to the problem under investigation.

Even though the approach presented here is based on the use of typologies (i.e. typologies of farming systems and typologies of rural households in the first and second case study respectively), and the aggregation of the variables across scales, it is also able to integrate qualitative and quantitative assessments (historical, institutional and participatory analyses versus indicator scores calculation, statistical analyses) related to different dimensions and scales. The latter characteristic makes the approach a good instrument for the analysis of sustainability in relation to a variety of purposes related to the field of science for governance. In fact, when evaluating a policy that might have wide impacts on different dimensions, as is generally the case when dealing with rural development strategies, an integrated and multidisciplinary assessment is needed to have an idea of the trade-offs. Based on these premises, it is proposed here that the use of multi-criteria and multi-scale approaches represent an added value towards the evaluation of rural development strategies.

On future research

The thesis has shown how to utilize, two complementary, complex, multi-scale evaluation tools and their possible integration. As explained in the section above, the combination of the use of the two methods, in the Chinese case study, has proved to be useful in a wide range of aspects. However, since the simultaneous use of the two methods represents an innovative contribution to the always increasing research on social systems as complex systems, the analysis could be improved with the realization of further research. For example, more effort may be put in the integration of the two methodologies since the beginning of the analysis. Especially in the investigation phase, in which the two approaches are applied separately and then combined in the evaluation phase. In other words, the MuSIASEM is used to help generate data and to specify sub-variables for an inclusion, during the evaluation phase, in the SMCE framework. A future research should look at possible ways of integrating the two models through all the phases of the investigation for the purpose of creating a unique framework.

Another issue which could be dealt with the work presented here is the explicit comparison of the two case studies. Such comparison would introduce a political meta-level of analysis, i.e. a sort of hierarchical level representing the rural political strategies of Europe/Italy and China. This would require the creation of a new hierarchical structure in which the political level is represented as the higher level. This analysis has been done briefly in chapter 2 but needs to be further developed with the collection of additional data and information. Moreover, another interesting possible future research may include analyses on the social desirability of rural migration strategies in the rural area of China under investigation. At the same time, it could be used for the analysis of the social conflicts between political decisions and the various social actors involved in the issue. To do that, new field work based on a specific participatory analysis appears to be necessary.

Finally, an aspect that needs further research is the spatial scale. In both case studies, the scale analyzed with the selection and evaluation of site specific indicators are local, i.e. village, household, farm. The inclusion of the regional and national scales, not just for the analysis of the policies and strategies, could help the definition of additional boundary conditions and constraints and the comprehension of the socio-economic and environmental dynamics that could have an influence on the local level. To do that the collection of additional data and information is needed.

APPENDICES

Appendix to chapter 3

Questionnaires

The questionnaires used are those to collect the information concerning the perception by farmers of the erosion phenomena (questionnaire 1 distributed to 22 farms located within the study area) and information for the calculation of criterion scores (questionnaire 2). The latter is divided into three parts: "information on the farm" which was given to 22 farms; "information concerning the growing of durum wheat" and "machinery use" which were given to the only 8 farms finally selected. The results related to questionnaire 1 are presented in tables 51, 52, 53 and 54.

Table 51 Question 1: In your opinion has the fertility and productivity of the soil worsened in the last few years?

questionnaires	Answers			Total preferences
	yes	not	I don't know	
22	14	8	0	22
100%	64%	36%	0%	100%

Table 52 Question 2: If yes, what in your opinion are the causes of this worsening?

questionnaires	Answers							Total preferences
	a	b	c	d	e	f	g	
22	4	7	2	6	2	0	3	24
100%	17%	29%	8%	25%	8%	0%	13%	100%

Table 53 Question 3: In your opinion what could be done to improve the condition of the soil?

questionnaires	Answers						Total preferences
	a	b	c	d	e	f	
22	0	9	10	3	1	0	23
100%	0%	39%	43%	13%	4%	0%	100%

Table 54 Question 4: If your company has not adopted any of the above mentioned interventions, can you explain why?

questionnaires	Answers						Total preferences
	a	b	c	d	e	f	
22	9	2	2	0	2	7	22
100%	41%	9%	9%	0%	9%	32%	100%

Questionnaire 1: The farmers' perception of the erosion processes in the study area

Agricultural practice (conventional, organic, integrated…)..........................

Farmer's age…………………………………………………......

1 - In your opinion has the fertility and productivity of the soil worsened in the last few years?

Yes ☐ No ☐ I don't know ☐

2 - If yes, what in your opinion are the causes of this decline?

a) major intensification of the modern agriculture ☐
b) use of chemical substances ☐
c) introduction of mechanization ☐
d) diffusion of monoculture intensive systems ☐
e) intensive stock farms ☐
f) deforestation ☐
g) Other (specifying) ……………………………………………………....... ☐
……………………………………………………………………………...

3 - In your opinion, what could be done to improve the condition of the soil?

a) to set aside farmland for at least 20 years ☐
b) to reduce substantially the use of fertilizer and/or plant protection products ☐
c) to introduce or continue with organic farming methods ☐
d) to use other farming eco-compatible practices, together with the maintenance of the countryside and the landscape ☐
e) to introduce low-intensity pasture systems ☐
f) Other (specifying) ………………………………………………………. ☐
…………………………………………………………………………….

4 - If your company has not adopted any of the above mentioned interventions, can you explain why?

a) for economic reasons ☐
b) because I don't know about interventions of this kind ☐
c) because of a lack of technical aid ☐
d) because I was in the dark about problems related to the soil degradation ☐
e) because of the incentives deriving from the CAP-Common Agricultural Policy lead me to prefer other choices ☐
f) Other ☐
(specifying)...............…………………………………………… …………………
……….....………………………………………………

Questionnaire 2: information about the farms.

General information:

- Type of agricultural practice (conventional, organic, integrated etc.).
…………………………………………………………………………………………………
……………………………………………………………………………………………
- Total surface area and surface area for each cultivation
…………………………………………………………………………………………………
……………………………………………………………………………………………
- Stock farms
……………………………………………………………………………………………
……………………………………………………………………………………………
- Crop rotations
……………………………………………………………………………………………
……………………………………………………………………………………………
- Type of cultivation (ploughing, minimum manufacturing, not worked)
…………………………………………………………………………………………………
……………………………………………………………………………………………
- Average productivity of the cultivation of durum wheat
…………………………………………………………………………………………………
……………………………………………………………………………………………

Information concerning the cultivation of durum wheat:

- Amount of durum wheat yield per hectare (year 2003) ....…………………
……………………………………………………………………………………………
- Type of seed and amount sowed (year 2003) …………………………………………….
……………………………………………………………………………………………
- Fertilizers, manures and plant protection products used for the growing of durum wheat: type, amount and price (year 2003)………………………………………………………
…………………………………………………………………………………………...

Machinery used

Machinery used specifying the horse power and hours per hectare for each stage of crop-growth

- Ploughing
…………………………………………………………………………………………………
……………………………………………………………………………………………
- Preparation of the soil bed
…………………………………………………………………………………………………
……………………………………………………………………………………………
- Sowing
…………………………………………………………………………………………………
……………………………………………………………………………………………
- Fertilizing
…………………………………………………………………………………………………
……………………………………………………………………………………………
- Harvest
…………………………………………………………………………………………………
……………………………………………………………………………………………

Sensitivity analysis

A sensitivity analysis is performed in order to elucidate conflicts among alternatives and objectives and to test the robustness of the model. The sensitivity analysis is realized changing the parameters defined by the operator (α and τ parameters, see the paragraph 2.8.1), considering also higher and lower crossover values and different operators: minimum, zimermann-zysno and simple product. The crossover values are the points where the preference relation reaches a credibility index of 0.5 (where it begins to be sufficiently credible). The crossover values have been evaluated on the maximum and minimum distance (see tables 55 and 56). The results show that the final evaluation is stable and organic practice is always preferred (see tables 57, 58, 59 and 60).

Table 55 Crossover values calculated on the minimum distance

Criteria \ Preference relation	C>> Very better	C> Better	C ≅ Approx. equal	C == Equal
GSP	18.69	14.02	4.67	1,00
Direct costs	27,00	20,25	6,75	1,35
Energy efficiency	0,27	0,20	0,10	0,01
Soil compacting	3,00	2,25	0,75	0,15
Soil erosion	0.54	0.41	0.14	0.30

Table 56 Crossover values calculated on the maximum distance

Criteria \ Preference relation	C>> Very better	C> Better	C ≅ Approx. equal	C == Equal
GSP	66.04	49.53	16.6	3.30
Direct costs	141,00	105,75	35,25	7,05
Energy efficiency	0,62	0,47	0,16	0,03
Soil compacting	21,00	15,75	5,25	1,05
Soil erosion	0.54	0.41	0.14	0.30

Table 57 Sensitivity analysis with Simple Product and Minimum operators, minimum and maximum distance

α	0.1		0.2		0.3		0.4	
Crossover value	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
Minimum	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ B ↓ A
Simple product	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ ↘ A B	C ↓ B ↓ A

Table 58 Sensitivity analysis with Simple Product and Minimum operators, minimum and maximum distance

α	0.5		0.6		0.7		0.8	
Crossover value	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
Minimum	C ↓ ↘ A B	C ↓ B ↓ A	C ↓ ↘ A B	C ↓ B ↓ A	C ↓ ↘ A B	C ↓ B ↓ A	C ↓ ↘ A B	C ↓ B ↓ A
Simple product	C ↓ ↘ A B	C ↓ B ↓ A	C ↓ ↘ A B	C ↓ B ↓ A	C ↓ ↘ A B	C ↓ B ↓ A	C ↓ ↘ A B	C ↓ B ↓ A

Table 59 Sensitivity analysis with Zimermann-Zysno operator and minimum distance

γ (Degree of compensation) \ α (Credibility index)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.1	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B
0.2	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B
0.3	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B
0.4	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B
0.5	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B
0.6	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B
0.7	C → B → A	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B
0.8	C → B → A	C → B → A	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B

Table 60 Sensitivity analysis with Zimermann-Zysno operator and maximum distance

γ (Degree of compensation) \ α (Credibility index)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.1	C → A; C → B	C → A; C → B	C → B → A	C → B → A	C → B → A	C → B → A	C → B → A	C → B → A
0.2	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → B → A	C → B → A	C → B → A	C → B → A
0.3	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → B → A	C → B → A	C → B → A	C → B → A
0.4	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → B → A	C → B → A	C → B → A	C → B → A
0.5	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → B → A	C → B → A	C → B → A	C → B → A
0.6	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → B → A	C → B → A	C → B → A	C → B → A
0.7	C → B → A	C → A; C → B	C → A; C → B	C → A; C → B	C → A; C → B	C → B → A	C → B → A	C → B → A
0.8	C → B → A	C → B → A	C → A; C → B	C → A; C → B	C → A; C → B	C → B → A	C → B → A	C → B → A

Appendix to chapter 4

Statistical analysis (Multivariate analysis)

This appendix gives some information related to the multivariate statistical analysis performed for the clusters' construction.

<u>*Elicitation of the informative variables for the clusters' construction*</u>

From the initial 44 variables 22 have been finally used to obtain the clusters.

The selection of the variables has been based on their variability (standard deviation and variation coefficient-VC), their correlation and finally on the final objectives of the research. Table 61 shows the initial 44 variables considered and their basic statistics: mean, standard deviation and the variation coefficient (VC).

The final 22 variables used for the clustering procedure have been: the hours of human activity, the income and expenditures and the land use related to different crops. The other variables, i.e. consumption, other land uses, number of livestock and income from husbandry, have been discarded because they were considered not relevant either taking into account the objective of the research (such as the variable "consumption", mostly related to the number of components; number of livestock and income from husbandry, only related to a small number of households) or from a statistical point of view (i.e. low variability, such as the variable "other land uses").

Table 61 Informative variables and their descriptive statistics

n.	Variables	Mean	Std. deviation	VC
	Hours of human activity			
1	Agriculture	9.756	5.185	0.531
2	Industry	6.256	7.431	1.188
3	Trade & services	1.430	4.189	2.929
4	Aquaculture	0.140	1.286	9.220
5	Livestock	0.360	0.975	2.706
6	Others	2.308	2.046	0.887
7	Sleeping	20.547	5.648	0.275
8	Eating and personal care	6.628	2.236	0.337
9	House working	4.930	1.903	0.386
10	Leisure and education	6.564	4.099	0.624
11	Others	0.802	1.964	2.448
	Income and expenditures			
12	Industry	11830.465	16227.929	1.372
13	Trade & services	2348.837	6856.956	2.919

n.	Variables	Mean	Std. deviation	VC
	Income and expenditures			
14	Agriculture	6098.140	4655.041	0.763
15	Aquaculture	209.302	1929.672	9.220
16	Livestock	175.814	822.476	4.678
17	Others	1120.000	2600.918	2.322
18	Income	21782.558	16169.242	0.742
19	Expenditures	10526.395	8398.264	0.798
20	Net income	11256.163	11486.763	1.020
	Land use (ha)- agriculture			
21	Agriculture	0.418	0.292	0.698
22	Wheat	0.051	0.050	0.994
23	Rice	0.056	0.047	0.842
24	Corn	0.143	0.139	0.974
25	Vegetable	0.162	0.136	0.837
26	Fruit	0.002	0.009	5.533
27	Sheep	0.000	0.001	6.875
28	Crab	0.005	0.043	9.220
	Other land uses (ha)			
29	House	0.009	0.003	0.307
30	Homestead area	0.016	0.003	0.209
	Consumption			
31	Water	11.419	11.216	0.982
32	Electricity	38.698	23.696	0.612
33	Liquefied gas	15.511	23.660	1.525
34	Fuel	4.523	18.757	4.147
35	Firewood	24.419	66.361	2.718
36	Grain	414.209	134.303	0.324
37	Meat and fish	148.116	69.300	0.468
38	Vegetable	713.512	342.241	0.480
39	Fruit	63.488	36.924	0.582
	Number of livestock			
40	Sheep	0.477	1.336	2.802
41	Poultry	0.058	0.536	9.220
	Income from husbandry			
42	Poultry	3.488	32.161	9.220
43	Sheep	139.535	554.743	3.976
44	Crab	209.302	1929.672	9.220

Scale of intensity for the classification of the working activities

The ranges for the construction of the scale of intensity per each cluster have been obtained by means of the descriptive statistics calculated for each variable, such as: "mean", "upper bound on mean" and "lower bound on mean".

Table 62 General statistics of the variables related to the income generation – (RMB/year)

Variables / Statistics	Industry	Trade and services	Agriculture	Aquaculture	Livestock	Others
Lower bound on mean (95%)	8,331	870	5,094	-207	-2	559
mean	11,830	2,349	6,098	209	176	1,120
Upper bound on mean (95%)	15,330	3,828	7,102	625	353	1,681

Based on the values related to the "lower bound on mean" (b_1), "mean" (b_2), "upper bound on mean" (b_3) indicated in table 62, the different contribution of the activities have been classified based on a qualitative scale, as follows: very low if $x_i < b_1$; low if $b_1 < x_i < b_2$; high if $b_2 < x_i < b_3$; very high if $x_i > b_3$. Where x_i represents the value of the income generated by the working activity i (agriculture, industry, trade and services, aquaculture, livestock, others) as indicated in table 63.

Table 63 Income generated by different working activities and clusters (RMB/year)

Activities / Clusters	Agriculture	Industry	Trade and services	Aquaculture	Livestock	Others
C1	9,070	6,920	0	0	0	50
C2	0	31,623	0	0	0	0
C3	12,886	0	0	0	36	2,704
C4	9,709	4,075	0	0	75	5,965
C5	5,922	0	0	0	0	816
C6	8,522	0	0	0	2,233	680
C7	0	23,289	19,111	0	0	0
C8	7,220	0	24,000	18,000	0	0

Questionnaires for data collection

This section shows the questionnaires used for the collection of the data at the household and village levels, as well as questionnaires used for the collection of technical information related to agriculture in Chongming island.

Data have been collected interviewing 207 households, agricultural technicians and the head of Hongxing village, in a period of four month field work (from October 2008 to January 2009) realized partially in Chongming and partially in Shanghai.

The questionnaires have been realized with the help of experts of Chongming island of the Shanghai Academy of Environmental Sciences (SAES).

In the questionnaires, "mu" represents the most common unit of measurement in China for area and square measures. The conversion with hectares and acres is as follows:

1 mu = 0.067 hectare = 0.164 acre

Moreover, RMB - Renminbi (people's money) is the Chinese currency.

Questions to the households in Hongxing village

The following questionnaire relates to the collection of data at the household level. Information relates to the following main categories: human time, economic information, land use, energy and food consumption, technical agricultural information.

1) General information about the respondent:

Age		Gender	
Member No.		Level of education	
Region of provenience		Years of settlement in Chongming	
House Area (m^2)		Homestead Area (m^2)	

2) Economic information:

2.1 Revenues

Activities:	**RMB/year**	**Months worked during the year**
Agriculture Crops		
Industry		
Trade and Services (including Transportation)		
Aquaculture (including Fishing)		
Livestock		
Others (specifying) ………………………………………………..	………………	…………………………

2.2 Expenditures

Cash consumption expenditures	RMB/year (average value)
Food	
Clothing	
Housing	
Furniture, Electronic Devices and Cars	
Health care and medical services	
Transport and telecommunication	
Educational, cultural and recreation	
Others (specifying…) ……………………………………………………………	

3) Allocation of time:

Gender		Male			Female		
Age							
Relation							
Time Allocation during 24-hours Day (hours/day)	**Working (hours/day)**						
	Agriculture						
	Industry						
	Trade and Service						
	Aquaculture						
	Livestock						
	others						
	Sleeping						
	Eating, Personal Care						
	House working						
	Education and Leisure (including traveling)						
	Others						

4）Revenues and Costs in Agriculture:

Farm Activities			Revenues RMB/year	Cost of production RMB/year
Crops	Grain	Wheat		
		Paddy		
		Corn		
	Vegetable			
	Fruit			
Husbandry	Pig			
	Poultry			
	Sheep			
	Cow			
	Rabbit			
Aquaculture	Fish			
	Crab			
	Shrimp			

5）Technical information agriculture:

Crops **Data**	Grain	Vegetable	Fruit
Planting Area (mu)			
Yield (kg/mu/year)			
Labor (including hired work) (RMB/mu/year)			
Proportion for Sale (%)			

Livestock	Pig	Cow	Sheep	Poultry	Rabbit
No./ year					

Aquaculture	Fish	Crab	Shrimp
Kg/year			

5.1 Can you please list below the crops you are planting this year, the mu and yield for each one?

Crops	mu	Yield （kg/mu）

5.2 Can you please list below the main rotating crops and the rotation period for vegetables and grains?

The rotation period of grain-planting plot is
…………………………………………………………………………………………………
The main rotating crops and their growing time are:
………………………………………………………………………………………………….
The rotation period of vegetable-planting plot is:
………………………………………………………………………………………………….
The main rotating vegetables and their growing time are:
…………………………………………………………………………………………………

6）Dietary information and resource consumption

Food Consumption	Grain	Meat, Egg and Fish	Vegetable	Fruit
Amount (kg/month)				
Energy Consumption	Water (ton/month)	Electricity (kilowatt/month)	Liquefied Gas (kg/month)	Fuel (liter/month)

<u>Questions to the head of Hongxing village</u>

The following questionnaire relates to the collection of data at the village level. Information relates to the following main categories: demographic distribution, economic information, land use, technical agricultural information.

1) **Demographic information and population characteristics**

1.1 Can you please indicate the demographic composition of the residents in the village?

Total number of residents per age classes and gender	**Gender**	
	Male	**Female**
Total population		
Age classes		
0-5		
6-11		
12-17		
18-65		
65-		

1.2 Can you please indicate in absolute terms the composition of the population (rural vs. urban)?

Composition of the population (rural vs. urban)	**Absolute values**
Urban	
Rural	

1.3 Main characteristics of the urban population.

Urban population	**Main industrial activities**	**Income per capita of urban population (RMB/year)**
Urban		

1.4 Can you please indicate the main areas where urban population of the village goes to work and the main industries?
………
………

2) **Land use and agricultural information**

2.1 Can you please indicate the land use of the village according to the following categories?

Land use	**Mu**
Urban area (Housing)	
Industrial area	
Cultivated area (including main cultivations) Fruits Vegetables Wheat Paddy Corn	 ………………………………… …………………………………. ………………………………… …………………………………. ………………………………… ………………………………….
Pond area for aquaculture and fishing	
Gardening	
Forest area	
Others (specifying)	

2.2 Can you please indicate in the following tables the information related to cultivations, livestock rising and aquaculture production in the Village?

Crops	**Paddy**	**Wheat**	**Corn**	**Vegetables**	**Fruits**	**Gardening**
Yield (kg/mu/year)						
Percentage for subsistence						

Livestock	**Pork**	**Rabbit**	**Chicken**	**Ducks**	**Sheep**	**Cattle**
Number of animals						
Percentage for subsistence						

Aquaculture and fishing	**Fish**	**Crab**	**Shrimp**
Production (kg/year)			
Percentage for subsistence			

Questions to the agricultural technicians

The following questionnaire has been used to collected information related to the Dongtan modern agricultural area (agricultural park). The information obtained has been used for the estimation of the indicators related to scenarios 2 and 3.

1) Information for the technical coefficients evaluation

1.1 Can you please indicate the main cultivations in the Dongtan area and the following technical information for each of them? (Average values)

Crops	Paddy	Wheat	Corn	Vegetables	Fruits	Gardening
Yield (kg/mu/year)						
Water use (kg/mu/year)						
Fertilizers (kg/mu/year)						
Chemical Pesticides (kg/mu/year)						
Use of tractors (type and power)						
Seeds (kg/mu/year)						
Market Price (RMB/Kg)						
Cost of production (RMB/mu)						
Labor cost (RMB/mu)						
Hours of labor (hours per year)						
Number of workers per year						

1.2 Can you please indicate the activities realized during the year for all the cultivations, specifying the hours of work per each month? (average values). (h = hours)

Crops: …….. **Activities**	Jan (h)	Feb (h)	Mar (h)	Apr (h)	May (h)	June (h)	July (h)	Aug (h)	Sept (h)	Oct (h)	Nov (h)	Dec (h)

2) Land use

2.1 Can you please indicate the land use of the SIIC Dongtan and the Dongtan Modern Park? (Unit of measurement: mu including urban area, cultivation area and main cultivations, forest area, gardening, industry etc..)

Land use	**Mu**
Urban area (Housing)	
Industrial area	
Cultivated area (including main cultivations) Fruits Vegetables Wheat Paddy Corn	
Pond area for aquaculture	
Gardening	
Forest area	
Others (specifying)	

Agroinnova eco-agricultural project: selected figures related to conventional and organic agricultural practices in Chongming island

Next table shows the results obtained by the eco-agriculture experimentation done by Agroinnova (Center for the Innovation in the Agricultural Sector) between 2005 and 2008 in Dongtan agricultural area within the project "Organic Farming Systems and Techniques for the Promotion of Green Agriculture in Dongtan Chongming Island", in collaboration with SIIC Dongtan and the Shanghai Academy of Environmental Sciences (SAES). The data presented have been used for the evaluation of the criteria in relation to scenario 3 (eco-agriculture).

T**able 64** Organic agriculture in Dongtan agricultural area. Absolute values with respect to conventional practices

	Average revenue (RMB/ha)		**Hours of work (ha/year)**		**Water use (l/ha/year)**		**Use of pesticides (kg/ha/year)**		**Use of phosphorus (kg/ha/year)**		**Use of nitrogen (kg/ha/year)**	
	Org.	Conv.	Org.	Conv.	Org.	Conv.	Org.	Conv.	Org.	Conv.	Org.	Conv.
Fruits	60.000	50.000	1800	1400	10000	12000	8	6.4	35	140	80	240
Vegetables	80.000	40.000	5800	5600	8000	8500	4.2	7.4	80	140	100	130
Wheat	40.000	30.000	1000	800	5000	6000	3	4	50	70	100	150
Paddy	50.000	40.000	1500	1300	20000	20000	5	6	50	70	120	160
Corn	70.000	25.000	1400	1100	12000	15000	7	7.2	80	90	200	300

Source: Agroinnova eco-agricultural project (Sino-Italian Cooperation project, 2008)

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