Exploring the links between agricultural biodiversity, ecosystem services and human well-being. Evidence from the Yucatán, Mexico.

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Abstract

This paper hypothesises that the application of an integrated and multidimensional human well-being - ecosystem approach can improve our understanding of agricultural biodiversity and the ecosystem services it provides in terms that are meaningful to the people that depend on them, allowing us to draw relevant public policy implications. We adopt and test the Capability-Ecosystem Approach (Duraiappah, 2004) by assessing strengths and weaknesses of its empirical application and ultimately contributing to its operationalization. Specifically, we tailor this approach to analyse the relationship between agricultural biodiversity, ecosystem services and human well-being in the Yucatán rural areas, Mexico, where farmers are among the poorest inhabitants of the total Mexican population. These area is of particular interest as Mayan farmers use and depend from a wide variety of natural resources, mostly agrobiodiversity, which represents a fundamental element of their culture and traditional knowledge.

Key words: agrobiodiversity, ecosystem services, multidimensional well-being, Mayan farmers, rural livelihoods

Introduction

Today there is growing international recognition of the contribution of biodiversity and the ecosystem services it supports to human well-being, although the debate is complex and there is uncertainty on the extent and quality of this contribution. The UN General Assembly declared that "preserving biodiversity is inseparable from the fight against poverty" (UN General Assembly, 2010), and EU leaders endorsed a long-term vision: "By 2050, European Union biodiversity and the ecosystem services it provides — its natural capital — are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human well-being and economic prosperity" (European Commission, 2010). There is therefore a call for researchers from different disciplines to improve the understanding of the relationship between human well-being and the ecosystems on which it relies.

This research paper proposes an alternative approach to the one-dimensional measurement of well-being in order to explore and evaluate multidimensional links between human well-being and the

ecosystem services provided by agricultural biodiversity and derive relevant implications for policy focusing on the development - environment nexus. The reason for this research resides in the assumption that human well-being is intimately tied to biodiversity and ecosystem services (Jones and Vincent, 1998; Duraiappah and Naeem, 2005; Gowdy et al., 2009; Ring, 2010; Roe, 2010). There are however few studies describing the multidimensional synergies and trade-offs between the ecosystem services provided by agricultural biodiversity and human well-being, while evaluation of assumptions, policy instruments and practices is badly needed (Carpenter et al., 2009; Barrett et al., 2011). Moreover, although the multidimensionality of these links is widely acknowledged, applied research and policy-making have focused mainly on monetary and asset-based techniques to analyse them (Comim, 2004; Duraiappah, 2004).

Agricultural biodiversity conduce to human well-being directly and indirectly through its contribution to material well-being, influencing security, health, social relations, resiliency and ultimately contributing to what people value doing and being (Dasgupta, 2001; Tilman, 1997; Perrings et al., 1995; Duraiappah and Naeem, 2005; Roe, 2010). On the other side, human actions impact ecosystems and biodiversity through indirect factors such as demographic, economic, socio-political, and cultural drivers. These processes determine for instance direct changes in local land use and cover, resources consumption, or species introduction, which in turn determine changes in human well-being (Young et al. 2005; Millennium Ecosystem Assessment, 2005; Berrett et al., 2011. Natural resources are being drawn down by global growth of consumption especially of higher income classes emitting wastes into natural sinks, reducing the stock of ecosystem assets and the flow of its services. On the other side there is strong evidence that poor people rely more heavily than others on ecosystem services and biodiversity because of the lack of alternatives, as a risk management strategy or to diversify livelihood options during bad times (Chambers, 1997; Duraiappah and Naeem, 2005; Ring, 2010; Roe et al., 2011).

This paper hypothesises that the application of an integrated and multidimensional human well-being - ecosystem approach can improve our understanding of agricultural biodiversity and the ecosystem services it provides in terms that are meaningful to the people that depend on them, allowing us to draw relevant policy implications. We adopt and test the Capability-Ecosystem Approach (Duraiappah, 2004) by assessing strengths and weaknesses of its empirical application and ultimately contributing to its operationalization. Specifically, we tailor this approach to analyse the relationship between agricultural biodiversity, ecosystem services and human well-being in the Yucatan rural areas, Mexico, where farmers are among the poorest inhabitants of the total Mexican population. These area is of particular interest as Mayan farmers use and depend from a wide variety of natural resources, mostly agrobiodiversity, which represents a fundamental element of their culture and traditional knowledge.

The Capability-Ecosystem Approach is an alternative to the study of links between ecosystems and human well-being based mainly on provisioning services as it adopts a paradigm and methodology which include other aspects of human well-being in addition to material wealth. Through the application of this integrated approach we also aim to contribute to the understanding of trade-offs and synergies between ecosystems and human well-being by taking into account the effects of multiple drivers influencing this relationship and the potential feedbacks that characterize it.

The research background

Biodiversity and the ecosystem services that it provides and supports should be understood in a socio–ecological context. Drivers that affect biodiversity, however defined, have direct effects on ecosystem services, and these changes in ecosystem services may then evoke feedbacks through human responses (Berrett et al., 2011; Carpenter et al., 2009). In this study we recognize that biodiversity and human well-being are linked in a mutual influence relationship through the provision and use of complex ecosystem services. However, most economic research on the relationship between biodiversity and human well-being has focused on socio-ecological interactions in terms of provisioning services (Comim, 2004; Duraiappah, 2004; Millennium Ecosystem Assessment, 2005). These services include among others food, fuel and fiber, and are easier to observe and measure directly, for instance through the willingness of people to pay, which however depends on the distribution of income. Provided that the links between biodiversity and human well-being are multidimensional, complex, and involve ethical, equity, distribution and spiritual concerns these issues are seldom taken into account by conventional economic analysis. It is therefore essential to understand the social–ecological context in order to understand biodiversity effects on human well-being and the drivers that affect it (Carpenter et al., 2009).

The focus of the proposed research is therefore on the complex interactions and linkages between biodiversity, specifically agricultural biodiversity, the ecosystem services it provides and their influence on the multidimensional constituents and determinants of human wellbeing.

In order to contextualize the research, a short summary is provided on the main issues involved in studying human well-being, biodiversity, and ecosystem services, and the complex interactions shaping their interrelationship.

Defining human well-being

Well-being as a concept takes many facets that change according to the information one wants to stress in its definition: welfare, quality of life, living standard, utility, life satisfaction, human development, capability expansion and so on. In reality these different meanings are not clearly distinct but have many points in common, sometimes overlapping. Despite the wide recognition among development researchers

and practitioners that poverty is a multidimensional concept, relatively few empirical studies focus on factors other than income, expenditure and/or assets. Income is certainly an important and necessary mean to expand the opportunities of people to live the kind of life they value, but it is not an end for human life itself and the relationship between well-being an income is hardly straightforward. What two persons can achieve through the same commodity bundle differs depending on their physical condition, the cultural, social, political and geographical context they live in or the resources and services they have access to, the so called conversion factors (Sen, 1992, 1999b).

Poverty is generally associated with lack of goods and services or unsatisfied basic needs, often overlooking the fact that poverty is also a synthesis of political, economic and social rights. Moreover, while poverty is usually measured through the use of monetary poverty lines, many have demonstrated that there is no perfect correlation between income poverty and unsatisfied basic needs (for a summary review see: Boltvinik and Damián, 2003). There are in fact households above the poverty line that lack health, water, sewage and other services, not counting social and political capabilities that are not considered basic needs.

The indicators presently used to measure well-being are based mainly on direct measures of current material wealth, such as the gross national product (GNP) per capita but also in part the Human Development Index (HDI), which includes indicators of education and health but has been criticized for the implicit assumption of perfect substitutability of its components. For quite a long time, well-being has been therefore intended in utilitarian terms as something measurable through levels of pleasure or utility.

In the last twenty years however the conceptualization of wellbeing as a multi-dimensional concept has flourished. Among multi-dimensional measurement approaches there are the capability approach (Sen, 1999b, 1992, 1985), the intermediate needs approach (Doyal and Gough, 1991), the dimensions of wellbeing approach (Narayan et al., 2000), the human capabilities approach (Nussbaum, 2000), and the sustainable livelihoods approach (Adato and Meizen-Dick, 2002). The dimensions characterizing wellbeing identified by these and other approaches are numerous: affiliation, bodily integrity, health, freedom, self-esteem, economic security and so on. Gasper (2007) provides a brief and useful review of current human development theorists.

A large literature has spanned from Amartya Sen's critique of the accepted similarity of concepts such as self-interest, preference, choice, satisfaction and wellbeing, conflated in the term 'utility' (Sen, 1999b). Drawing from a multi-disciplinary perspective including sociology, anthropology and philosophy, Sen has emphasized the need to introduce qualitative and multi-dimensional information in the assessment of wellbeing and poverty. He focuses on functionings (achievements of a person) and capabilities (what a person values doing or being) meaning a person's ability and opportunity to activate and achieve a given functioning. The activation of these functionings depends on the person's choices

(she chooses to attend school) or not (if she is illiterate she cannot chose to read or write). It also depends on the person's preferences, as she will activate the functionings that she prefers. Someone's capabilities include only functionings that are or can be activated, while it excludes the ones that the person can't activate herself.

Prioritization of functionings and therefore capabilities is not made by Sen at a theoretical level but should be obtained through participatory approaches and context-based assessment. Participation is an essential component of the process aimed at increasing the wellbeing of people because public awareness and understanding of problems and remedies cannot be disjoined by the value judgements a society makes in a specific context and time. Sen thus avoids and refuses the drawing of a predefined list of fundamental capabilities. Others, such as Nussbaum, have developed lists of dimensions relevant to the definition of wellbeing, isolating those human capabilities that can be argued to be of central importance in any human life, whatever the person pursues or chooses. Nussbaum thus specifies a series of functionings to which all persons should have access. Doyal and Gough, for instance, argue that human beings have basic needs for physical health and autonomy, which they define as 'the ability to make informed choices about what should be done and how to go about doing it'. From these two basic needs they derive a range of so called intermediate needs connected to goods that are deemed essential to satisfy the basic needs. Finally, the sustainable livelihoods approach recognizes that the building blocks of livelihoods are assets and that they can be categorized as natural, social, human, physical, and financial assets. These assets are combined in the pursuit of different livelihood strategies, for instance agricultural intensification and livelihood diversification. Therefore we move forward from the space of determinants of wellbeing, such as commodities and income, to include also the constituents of wellbeing such as social relations, security, health, freedoms and choices (Reddy and Pogge, 2009; Dasgupta, 2001; Sen, 1999).

There is no doubt that many factors contribute to wellbeing, although less attention has been paid to determinants of wellbeing such as education, technological innovation in health, the time value of leisure and the direct dependency of many people on ecosystem services. Therefore, in order to tackle these different factors in the human wellbeing – environment relationship we apply the Capability-Ecosystem Approach developed by Duraiappah (2004), which draws on Sen's concept of freedoms and capabilities that enable people to function. The theoretical framework of this approach is summarized in the 'Theoretical Approach and Methodology' section.

Ecosystem services, Biodiversity and Human Wellbeing

Ecosystem services are defined as the processes and conditions of natural ecosystems that support human activity and sustain human life. This concept denotes the benefits people derive both directly and

indirectly from ecosystem functions, which are the habitat, biological or system properties or processes of ecosystems. An ecosystem service can be the product of two or more ecosystem functions, while more ecosystem services can be the product of a single ecosystem function (Chapin et al., 2000). We follow the definition of ecosystem services provided in the Millennium Ecosystem Assessment: Biodiversity Synthesis (Duraiappah and Naeem, 2005) which defines ecosystem services as:

1. Provisioning services: e.g. food, fiber, fuels, fresh water, genetic material, biochemicals;
2. Regulating services: e.g. purification of air and water, mitigation of droughts and floods, renewal of soil and soil fertility, maintenance of biodiversity, partial stabilization of climate;
3. Cultural services: e.g. social relations and values, aesthetic values, spiritual values

Underpinning all of the above are supporting services such as soil formation, primary production, photosynthesis, nutrient and water cycling. In economic terms there are many sectors and activities dependent on these services: such as agriculture, forestry, fisheries, pharmaceuticals, hunting on provisioning services; while regulating services potentially include a large variety of economic activity; and cultural services-related economic activities include tourism, recreation, and education. Regulating and supporting services in particular are essential for the steady delivery of provisioning services to humans and to sustain life on Earth, while cultural services are important for many people especially in developing countries where nature is often valued as a living entity supporting spiritual guidance and social relations (Duraiappah and Naeem, 2005; Duraiappah, 2004).

A recent study linking biodiversity, ecosystem services and employment illustrates through case studies how overlooking and underestimating the dependence of the poor on ecosystem services can lead to both negative outcomes in terms of livelihoods and ecosystems (Nunes, 2011). The authors found for instance that there is a strong link between employment and biodiversity through the ecosystem services it provides, especially in primary sectors and in developing countries, but not at all confined to these, and the degree of importance of this link depends on the substitutability with man-made goods and services.

While there is evidence of synergies between ecosystem services, human wellbeing and biodiversity, some apparent conflicts emerged with the so called ‘environmentalist’s paradox’, or that in recent decades improvement in wellbeing has occurred despite decreases in certain ecosystem services, as the Millennium Ecosystem Assessment reported (Millennium Ecosystem Assessment, 2005). A synthesis on some takes on why this paradox exists is provided by Raudsepp-Hearne et al., (2010).

One undervalued view of the paradox is based on the assumption that critical dimensions of human-wellbeing are not captured adequately by standard measures such as GDP or the HDI, and that accounting for other dimensions would show an actual decrease of human wellbeing linked to decreasing ecosystem services (Reddy and Pogge, 2009; Sen, 1999a). Moreover, most of the declining services found are regulating and supporting services, which have been largely overlooked in studying ecosystem links to

human wellbeing, while provisioning services have been expanding. These declines are of particular concern because of the vital role of regulating and supporting services in underpinning provisioning services.

There is therefore an on-going debate on the fact that an important reason for the decline of ecosystem services is that their true values are not taken into consideration in standard economic decision making, which in ultimate analysis are based on the aforementioned global indicators of wellbeing (Balmford, 2002)[1]. Therefore, in order to address the distributional dimension of the provision of ecosystem services and livelihood dependence upon them there is a need for improved instruments to measure economic welfare and human wellbeing (TEEB, 2008).

In this research we focus on ecosystem services provided by biodiversity in terms of provisioning, enriching and, partly, regulating services. Biodiversity is defined by the Convention on Biological Diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems". The economics of biodiversity is a complex and rather recent field and it implies not only the determination of a set of state variables that characterize a complex ecosystem but also understanding the function of biodiversity within the ecosystem, as a source of ecosystem productivity and health, for instance through its support to stability and resilience (Dasgupta, 2001; Tilman, 1997; Perrings et al., 1995; Holling, 1996, 1995, 1973). When a natural-resource base is depleted, it affects not only the volume and quality of ecosystem services it provides but also its capacity to absorb disturbances without undergoing fundamental changes in its functional characteristics (Dasgupta, 2001). Biodiversity therefore plays a fundamental role for ecosystem functions that provide supporting, provisioning, regulating, and cultural services.

Furthermore, there seems to be an intimate relationship between extreme poverty, inequality and rapid loss of biodiversity, especially in those geographical hot spots where rural livelihoods depend strongly on nature (Barrett et al., 2011). Poor people are often hit hardest by biodiversity loss because they depend more directly and more heavily on biodiversity and ecosystem services (Gowdy et al., 2009; Sukhdev, 2009). Biodiversity is in fact key to fertilizing soil, controlling erosion, pollinating many crops and trees, providing decomposers, natural enemies of pests and diseases, and genetic material. Moreover it is often used as a risk management strategy when crop fails or external stresses occur (Roe, 2011). Genetic resources for instance allow farmers and plant breeders to cope with heterogeneous and changing environments (Fowler and Hodgkin, 2004), an issue particularly important under the pressures of climate change. Moreover, the rural poor often depend on biodiversity for food, shelter, medicines and many other

1 An influential and largely criticized study by Costanza (1997) estimated the value of the world' ecosystem services, boosting discussion and research on the matter.

aspects of their lives (Jones and Vincent, 1998). Industrialization, poverty, population increase, infective diseases and climate change have disrupted local practices endangering livelihoods and biodiversity. This genetic erosion implies lower adaptability to marginal and fragile ecosystems and to low-input agriculture (Bellon, 2006). Dietary diversity and appropriate nutritional intake, for instance, are partially dependent on genetic resources. Unnumbered crop varieties and domestic animal breeds have disappeared, while fishing grounds are exploited at or above their sustainable limits. The resulting diet simplification has negative impacts on food security and health (Love and Spanner, 2007). Low-caste, tribal, and poor rural women are especially dependent on the environment for water, fuel, fodder and food, and they are the first to be adversely affected by environmental degradation, biodiversity loss and climate change (Bellon, 2006). These particularly vulnerable groups often don't have access to necessary resources because of their household or community social status (Roy and Venema, 2002). Moreover, cultural traditions, religious beliefs and the identity of communities around the world are also intimately tied to food and spiritual practices connected to biodiversity. Therefore, biodiversity loss is detrimental to local identity and good social relations, particularly in marginal areas (Posey, 1999).

The many interlinkages between biodiversity and human wellbeing can also be understood in terms of the apparent feedback loops between biodiversity loss and poverty traps, as described in Barrett et al. (2011). The authors define four classes of interlinkages between (tropical) biodiversity and poverty traps:

1. Dependence on inherently limited natural resources: the growing conversion of forest and lands or overharvesting to satisfy consumption determines feedback loops between environmental degradation and deterioration of human wellbeing. This is accentuated by the complementary relationship of the rural poor with nature, the quantity and quality of which determines returns to labour (poverty-environment trap). Moreover, the non-linearity that characterizes natural processes increases the possibility of coupled collapse or abundance in human wellbeing and biophysical resources.

2. Shared vulnerabilities: large scale processes and consumptive tendencies heavily influence the choice of response of households to different pressures as well as biodiversity dynamics independent of household behaviour. Where natural shocks such as drought or flood are regular, the feedback loops between poverty, population growth, migration, and environmental degradation are reinforced.

3. Failure of social institutions: market, political and institutional failures, which often happen simultaneously, can lead to poverty traps and ecosystem collapse if formal property rights or informal social norms and cultural practices are not aimed at controlling self-interested individual behaviour.

4. Unintended consequences and lack of informed adaptive management: there might be imperfect informational feedback due the difficulty in anticipating the outcomes of decisions affecting the

environment, such as downstream changes that become visible after a period of time, making response more costly.

Finally, biodiversity services are non-exclusive and biodiversity stocks are difficult to monitor. On the other side property rights to biodiversity may be difficult to establish, therefore effective biodiversity protection requires strong enforcement institutions. Many natural resources are in fact 'open access' and not covered by property rights or effective national laws and international treaties, which leads to their constant depletion. For example, open access and a perverse system of subsidies have left two-thirds of fish stocks across the globe over-exploited, and have damaged coastal ecosystems (Sukhdev, 2009). On the other side, high biodiversity is often rich in marginal lands, where private and public sector investments remain low, though they are critical for sustainable management of natural resources (Jha and Bawa, 2006). Governments are called to provide fiscal or other incentives to encourage the participation of involved stakeholders by reforming the way property and access rights are assigned, and through better targeting of taxes and subsidies (Sukhdev, 2009). Also, sustainable management of natural resources must also rely on the role of traditional practices for ecosystem management, which include multiple species management, resource rotation, ecological monitoring, succession management, landscape patchiness management, and practices of responding to and managing pulses and ecological shocks (Colding et al., 2003). These practices are linked to social mechanisms such as flexible user rights and land tenure; adaptations for the generation, accumulation and transmission of ecological knowledge; dynamics of institutions; mechanisms for cultural internalization of traditional practices; and associated worldviews and cultural values.

Duraiappah (2004) defines the crucial role of institutions and organizations in helping individuals to earn a sustainable income from the provisioning services offered by ecosystems in the sense that clear ownership of and easy access to a variety of resources is needed to make the conversion of natural resources into economic activities successful. Many of the natural resources upon which poor people depend for income generation which were traditionally under common property regimes governed by informal institutions have been closed to their access by the emergence of formal private property right regimes (Rutten 1992).

Distributive inequality and access to information and knowledge that allows the poor to manage their resources in the most economically efficient and ecologically sustainable manner is also linked to institutional settings and failure. The lack of information on prices, markets, opportunities, and sustainable technologies has been one of the driving forces for the poor to use the natural resources upon which they depend in unsustainable ways (Amman 2001).

Moreover, conventional resource management often fails to manage biological resources and diversity sustainably, especially in areas where local communities achieved long-term successful management of common pool resources (Holling & Meffe, 1996). A study of informal arrangements and institutions provides useful insights on how to improve resource management and conservation. Approaches have been studied and developed to recognize the role of collective action and social mechanisms in regulating such open access resources. Most notably, Ostrom (1999) reviewed and analysed communalities and differences of cases where communities have developed advanced context-dependent mechanisms to successfully manage common property.

The integration of a study of the role of institutions and traditional practices of managing biodiversity will improve the quality of this research and provide an analysis that accounts for the complex interactions between human activities, decision-making and the natural resources upon which they depend.

This research focuses on agricultural biodiversity (here on 'agrobiodiversity'), which refers to the diversity of living organisms (plants, animals, bacteria, etc.) used in agriculture (Wood and Lenne, 1999). The ecosystem that will be studied is an agroecosystem or "a biological and natural resource system managed by humans for the primary purpose of producing food as well as other socially valuable non-food goods and environmental services" (Wood and Scherr, 2000).

Specifically, we study the role of plant species diversity in providing ecosystem services relevant to human well-being and its interaction with human activity. Many traditional farmers in fact plant diverse crops not to enhance productivity but to decrease the chances of crop failure in a bad year. Species diversity also reduces the probability of outbreaks by 'pest' species by diluting the availability of their hosts (Chapin et al., 2000). There are also indices that the impoverishment of biological resources in many countries is linked to declines in community and cultural diversity, such as shown in diet, medicine, language and social structure (Harmon, 1992). These features are some indicators of the links between ecosystem integrity and economic and human wellbeing.

Theoretical Approach

In order to explore the links between biodiversity, the ecosystem services it provides and human wellbeing, we adopt the theoretical framework developed by Duraiappah (2004), defined as the Capability-Ecosystem Approach (CEA in short). This framework was developed to address three objectives: to demonstrate how human wellbeing is dependent on ecosystems and ecosystem services; to identify barriers and drivers that prevent the poor from using these ecosystem services to improve their wellbeing; and to identify policy response options to remove the barriers, re-design or even introduce new

intervention strategies to allow the poor to improve their wellbeing through an ecosystem approach (Duraiappah, 2004).

In this framework, poverty is defined as the pronounced deprivation of wellbeing (Chopra et al., 2005) and draws on Sen's concept of five freedoms (Sen, 1999b), which implies that a person possesses political capabilities (empowerment, rights, freedom of choice), economic capabilities (the ability to earn an income, access to land and resources, decent work), human capabilities (health, education, nutrition), socio-cultural capabilities (status, dignity) and protective capabilities (to address security, risk and vulnerability).

The CEA introduces a list of constituents and determinants of wellbeing closely related to ecosystem services1:

1. Being able to be adequately nourished.
2. Being able to be free from avoidable disease.
3. Being able to live in an environmentally clean and safe shelter.
4. Being able to have adequate and clean drinking water.
5. Being able to have clean air.
6. Being able to have energy to keep warm and cook.
7. Being able to use traditional medicine.
8. Being able to continue using natural elements found in ecosystems for traditional cultural and spiritual practices.
9. Being able to cope against extreme natural events like floods, tropical storms and landslides
10. Being able to make sustainable management decisions that respect natural resources and enable the achievement of a sustainable income

This approach therefore moves forward from the space of assets and income to the space of capabilities, focusing on what individuals value doing or being and on their ability to achieve these doings and beings through instrumental freedoms and choices. In order to conceptualize the natural environment this approach does not focus on a single environmental issue or species and recognizes that the ability of ecosystems to provide products for consumption and absorb human waste is declining (Duraiappah and Roy, 2007).

The links between ecosystem services and the ten constituents of wellbeing can be roughly summarized as follows:

- Provisioning services play an instrumental role in improving diets and providing relief during times of famine, crop failure, pest attack and drought; they include the provision of fresh water; most poor people depend on rivers and streams for their daily requirements; a large part of the world's population cooks with biomass derived by firewood, crop residues and animal dung;

traditional medicine is an integral part of the health care system of the poor. While unsustainable activities cause ecosystem degradation, natural resources are also among the main sources of income for the poor.

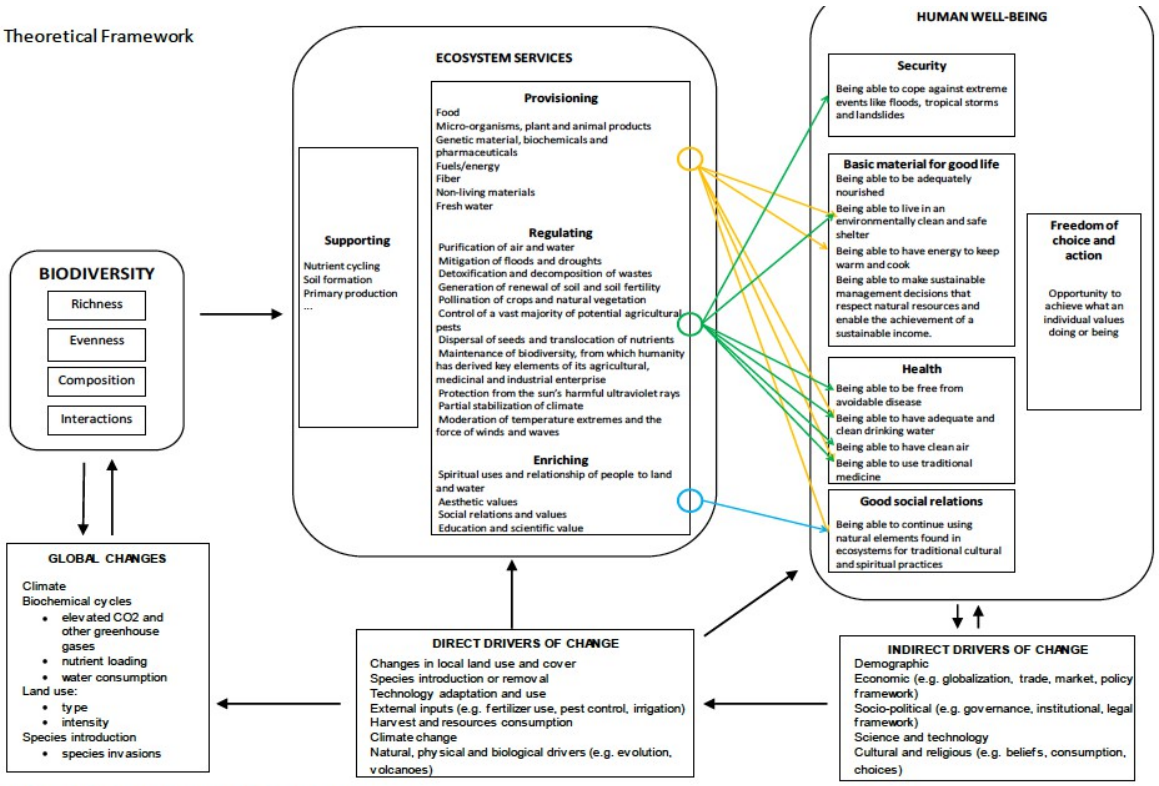
- Regulating services include the purification of air and water, which is fundamental considering that many diseases are linked to ecological conditions such as air and water pollution; the regulation of floods, landslides and the impacts of storms
- Many rural communities worship and attach spiritual or religious value to the natural environment, while many social activities and traditions revolve around local biodiversity

Therefore there are many linkages between ecosystem services and the constituents of human wellbeing, and through this interdependency many of them could improve by addressing some of the others.

The CEA approach also takes into account the direct and indirect drivers that impact ecosystems as well as the poor's access to and use of ecosystem services which include: economic drivers, governance-related drivers, social drivers and ecological drivers. The Capability-Ecosystem approach therefore provides a comprehensive framework to analyse the relationship between ecosystem services and human well-being. Moreover, this approach recognizes that different stakeholders use ecosystem services in different ways and have different degrees of dependency on these services, therefore analysis at the local scale is best fitted to explore the links between ecosystem services and human well being. This is even more relevant in view of the fact that the relationship between human wellbeing and the environment can only be understood within particular sets of institutions (Duraiappah and Roy, 2007).

The framework followed in this research is presented in Figure 1.

Figure 1: Theoretical Framework



Adapted from Duraiappah, 2004; Duraiappah and Naeem, 2005

Study Area: the Yucatán rural area

In line with evidence that the human well-being – ecosystem relationship is optimally captured on small municipality or community scale where the interaction among ecosystem constituents and human activity is observable, four municipalities of the Yucatán region where chosen for data collection and analysis (Duraiappah, 2011). Local conditions relate to the specific ecosystems and their services to the local communities, the economic activities, the social and cultural values, and, finally, the political and governance structures. Moreover, due to the rather economic than ecological nature of the research, the study areas were also chosen for the availability of data on agrobiodiversity and ecosystem services.

Mexico is a constitutional federal republic comprising thirty-one states and a federal district, the capital. In 2010 the Mexican population amounted to 112 million people, of which 26 million (23%) live in rural areas, defined as localities with less than 2500 inhabitants (INEGI, 2011). Mexico is a federal constitutional republic divided in 31 sovereign states, GDP per capita was 14,800 PPP dollars in 2011 and income inequality high with a Gini index of 51,7 in 2008. Mexico is an important centre of crop domestication and diversity resulting from biological events and the interaction between human populations and the natural environment for hundreds of generations (Bellon et al., 2009). The needs,

interests, practices and knowledge of these human populations have been forming and maintaining this diversity, and they continue to maintain and develop it even under increasingly difficult conditions.

The geography of Mexico, its variety of climates, topography and geological history concurred to the creation of one of the richest countries in the world in biological and cultural terms, as proven by the definition of Mexico as a megadiverse country. Conservation International forged this concept in order to give priority to conservation goals in 17 countries which possess as much as 70% of the biological diversity of the planet. Estimates indicate that Mexico maintains about 10% of all living organisms on earth (Toledo, 1988; Ramamoorthy et al., 1993). The total number of described species in the country is about 65 million (very well below the estimated 200 million in the country). Fauna is bout 171 million inverterbates and 5 million verterbrates, mainly fish and birds. Mexican flora has about 23 million species, with an endemism level above 40% (Groombridge & Jenkins, 2002). In terms of number habitats or eco-regions, Mexico is the most diverse country of Latin America (Dinerstein *et al.*, 1995).

The concept of biodiversity is closely linked to that of cultural diversity, as indigenous communities have collectively tried, selected, exchanged seed and used plants, insects and animals for food, medicine, shelter, clothing and spiritual practices for generations (Brush, 2007). Biodiversity is therefore also the result of a large and continuous process of selection and crossing, spontaneous or provoked by people.

On the side of rural institutions, in the early 20th century lands were reallocated under a community managed form, the *ejido*, which prohibited land transactions by activating a collective management of land resources (Bouquet, 2009). However, in 1992, individual titles were issued and lands could be sold, however the *ejido* remains active as a collective decision forum to decide on private property sales, for instance to outsiders of the *ejido*. The governments' objective was to define secure property rights in order to foster land market transactions and eventually agricultural growth. The actual results of this reform are mixed (Bouquet, 2009; Deininger et al., 2001).

Moreover, Mexico is one of the first countries to have officially adopted the multidimensional measure of poverty developed by Alkire and Foster through its application by the National Council of Evaluation of Social Development Policy - CONEVAL (Corona, 2007). According to this measure, in 2010 47.9% of the population in Yucatán was poor in multidimensional terms, with 9,8% of the population extremely poor (CONEVAL, Website).

The Yucatán state is located in the south east of Mexico, in the northern part of the Yucatán peninsula. It has a population of 1,9 million inhabitants in 106 municipalities, of which 16% lives in rural areas (less than 2500 inhabitants). Life expectancy is lower than national average, at 75 years, the state Human Development Index is high (more or equal to 0,80). A third of the states' population speaks Maya, while 9,2% of the population is illiterate, illiteracy is more spread among women (10.6%) than man

(7,8%) according to the latest Census (INEGI, 2010). Among the challenges facing the state there are a serious lack of formal employment, access to health services, water treatment, provision of sewage and waste collection, often due to the high dispersion of communities (OECD, 2008). The state can be virtually divided in two parts: the west-northeast region centered by the states' capital, Merida, and historically more open to external influence; and the southeast region, more isolated and with a stronger concentration of indigenous communities (Durán et al., 2010). The agricultural production system in the Yucatán peninsula is characterized by a predominant crop, maize, complemented by a set of secondary but nonetheless important crops such as beans, tomatoes, chilli peppers etc. and also by the use of non cultivated diversity, especially forest resources. This research therefore looks at the diversity of species conserved and used by the farmers.

Agrobiodiversity is a fundamental part of the agricultural strategy of Mayan farmers and therefore strongly linked to their culture. Following the traditional knowledge and beliefs of Mayan farmers, the natural environment and its components have a high value due to their perception of plants, animals, and rocks as 'beings' with something similar to a soul (Durán et al., 2010). Traditional practices such as the milpa system of slash and burn agriculture (roza-tumba-quema) have also a moral meaning in the fact that they affect and deeply change the natural environment. As a productive system, the milpa involves different activities from husbandry, beekeeping, home gardens, hunting, recollection of wood from the forest, and small commerce (Durán et al., 2010). It is a polyculture system that can involve the use of various fields (1st, 2nd, or 3rd year, after which they should be abandoned to fallow) with as much as 32 different species over a production cycle, with annual legumes like beans, squashes and pumkpins, and other crops. Mayan farmers know the value of biodiversity in that it protects them, mainly through pest control, so that its depletion is a threat both in material and in cultural terms. This strong cultural link between agrobiodiversity and the Mayan communities that use it is extremely interesting to this research and is taken into account.

Four municipalities were chosen for data collection and in depth study. Motul, in the northern part of the state is a former henequenera area with largest maquiladora in the state, which suffered a strong decline in agriculture and is advantaged by vicinity to the state's capital. Tekax, municipality in the south of the state, with higher economic growth and large presence of commercial farmers, recent maquiladoras and large juice producing plant. Tinum, small municipality with mainly subsistence farmers in the north east side of the state, close to major tourism spot; and Tzucacab, a southern municipality far from the state's capital, with a majority of subsistence farmers in marginalized villages, which are being abandoned by young people.

The sampled population was defined comparing so called 'peasant' and 'entrepreneurial farmers' in order to understand and compare the different use and value of agrobiodiversity both in marginal and commercially oriented areas. Peasant farmers are in fact characterized by a high degree of self sufficiency in terms of means of production and consumption of their own product; low access to credit and funding; production activities are performed by family members and animals; they are usually small holders; and livelihood strategies are based on a combination of practices including agricultural collection, domestic livestock, handicrafts, fishing, hunting and part-time work outside the house. On the other side, entrepreneurial farmers are characterized by adequate availability of funding and inputs; better quality soils; extremely specialized production; intensive mechanization; maximization of returns per unit of investment; high use of capital and adequate information systems on prices, markets and transport of inputs and outputs; high level of organization in the administration of the factors of production (Sepulveda, 1992).

The comparison is extremely interesting to assess the different dimensions of human well-being influenced by agro-biodiversity and its ecosystem services. In fact, peasant farmers in Mexico seemingly conserve and use a high level of biodiversity based on integration with the surrounding environment, while entrepreneurial farmers have low levels of agro-biodiversity due to monoculture, excessive application of chemicals, and depend heavily on subsidies. Peasant farmers in Mexico have been largely overlooked by government assistance, which has been directed to push forward largely subsidized 'modern' entrepreneurial farming. However undervalued by public policy their role in conserving genetic resources that they have domesticated through centuries, maintaining and improving selection practices and seed flow, is crucial (Bellon et al., 2009). Moreover, small peasant farmers depend directly on agro-biodiversity for consumption and production. The contrast between entrepreneurial and peasant farmers is likely to show significant differences when comparing one- and multi-dimensional measures of wellbeing linked to agro-biodiversity. By comparing the two groups of farmers the different dimensions of wellbeing that are influenced by the conservation and use of agro-biodiversity are assessed and related policy implications drawn.

Methodology

The Capability-Ecosystem Approach suggests a six-step methodology to explore the links between ecosystem services and human well-being (Duraiappah, 2004), which was modified to tailor this research:

1. Setting the stage:

- The study area was defined and a literature review of socio-economic characteristics, natural resources on which it depends focusing on local agrobiodiversity, and of the prevailing production systems was

carried out. Past and existing initiatives on the poverty-environment nexus were reviewed in order to identify what has been done, the information available and assess what is still needed.

- A preliminary list of determinants and constituents of human well-being was developed to adapt the one developed by Duraiappah to the study areas.

2. Well-being Assessment:

- Survey building: the household survey was developed based on secondary data collected in Step 1 and on key informants' interviews with people from the communities, academics, and development practitioners. Through interviews with academics and key informants from the communities such as farmer leaders and practitioners from rural government agencies relevant dimensions and indicators for the analysis of capabilities were defined. Table 1 shows a set of simple and measurable indicators on which the survey was based. The survey covered issues concerning capabilities relevant in the area; livelihoods assets, socio-economic data, social capital, and household expenditure; nutritional information; availability, production, marketing, use and consumption of native cultivars; and perceptions/values of native cultivars and their loss (enriching/cultural services). As the research was also part of an interdisciplinary project between the Universidad Autónoma de Yucatán and the International Center for Development and Decent Work (ICDD) of the University of Kassel, relevant topics to the project were covered in the survey[2]. These topics dealt with labor migration issues in farmer's households and to agriculture as an employment that falls under the definition of decent work. The survey was validated and adjusted in terms of language and concepts through preliminary applications to randomly selected people from the community and through adaptation by practitioners and academics who have knowledge of the study area and its dynamics.

Table 1: Relevant dimensions and indicators

DIMENSIONS	INDICATORS	SURVEY QUESTION
Being able to be adequately nourished	1. Food Consumption Score (WFP – FAO)	Nr. of times each food group was consumed during the past 7 days. Each food group has a predefined weight
	2. Access to food	Was there any time in the past year when food was not enough and why
	3. Availability	Where do you get 'food group' from (if it is grown by the household the data is triangulated with a question on how many months they can consume their own products)
Being able to be free from avoidable disease	1. Drinking water	What is the source of drinking water
	2. Waste	How do you dispose of household waste

2 The project “Agrodiversity, labor migration, decent work and development in Yucatán, México” funded by the International Center for Development and Decent Work (ICDD) of the University of Kassel and carried out by the Faculty of Medicine, Veterinary studies and Animal Husbandry of the Universidad Autónoma de Yucatán, financed all the fieldwork relatd activities of this research.

DIMENSIONS	INDICATORS	SURVEY QUESTION
	3. Toilet facilities	What is the toilet facility
	4. Access to health related services	Do you have access to clinic/hospital Do you have to pay for this service and is it expensive or not
Being able to live in an environmentally clean and safe shelter	1. House materials	What is the predominant material in roofs, walls and floors
	2. Cooking	Do you cook in the same room where you sleep
	3. Toilet facilities	What is the toilet facility Do you share toilet with another household
	4. Energy	Where do you obtain electricity
	5. Water	How many times per week do you have water (not drinking water)
Being able to have energy to keep warm and cook	1. Cooking	What do you cook with What is the source of the elements you cook with
Being able to have adequate and clean drinking water	1. Drinking water	What is the source of drinking water Where do you get drinking water and do you pay for it
Being able to use traditional medicine	1. Traditional medicine	Do you use any natural resource from your field for medicinal purposes Do you use any natural resource from the forest for medicinal purposes
Being able to continue using natural elements found in ecosystems for traditional cultural and spiritual practices	1. Ceremonies	Do you know traditional ceremonies linked to agriculture Do you practice traditional ceremonies linked to agriculture Do you use your own products for these ceremonies Is the ceremony collective or private
Being able to make sustainable management decisions that respect natural resources and enable the achievement of a sustainable income	1. Income from agriculture	Income gained from marketing of products (crops + forest resources + animals)
	2. Other sources of income	What other sources of income do you have
	3. Conservation	Do you participate in programmes linked to conservation of natural resources (PES, reduction of chemicals etc.)

- Definition of a representative sample: using farmers' lists drawn from public support programmes, which all and all cover most of the farmers population in the four communities, sample sizes representative of the population for each community were defined. We applied the following simple random sampling formula in order to allow all elements of each community's populations to be taken into account with the same probability with a 95% confidence level:

$$n = \frac{Z^2 \cdot p \cdot q \cdot N}{(N-1)e^2 + Z^2 \cdot p \cdot q}$$

Survey administration: survey was planned according to the availability of sampled households. Households were approached and interviewed directly (face to face): the part of the survey dealing with

household characteristics, nutrition and wellbeing was carried out with the farmer's spouse or the person who was in charge of the household, while the part relating to agriculture, agro-biodiversity and decent work was submitted to the farmer. Survey administration was carried out with the help of four university students throughout a period of three months and a half, from the last week of February 2012 to the first week of June 2012.3.

3. Ecosystem Assessment: definition of the ecological system and the ecosystem services upon the delivery of which the community depends from the analysis of available data, key informants interviews and survey results, with a focus on the ecosystem services linked to local agricultural biodiversity. The state and pressures on agricultural biodiversity in the study area will be derived from available scientific data in order to draw one or few reliable indicators linked to local agro-biodiversity.

4. Analysis of results and development of well-being indicators and of a socio-ecological model: econometric analysis of the data collected and cross checking with information gathered through secondary data, key informants' interviews and focus groups, will be carried out in order to develop a socio-ecological model of the interactions between agro-biodiversity and human well-being. The analysis will be carried out as a comparison between two models, one developed around a multidimensional wellbeing indicator through the Alkire-Foster methodology (Alkire and Foster, 2009) and another through a standard expenditure based indicator. The Alkire-Foster methodology to define a well-being indicator consists of an identification method that uses two forms of cutoffs (a concept similar to poverty lines):

a) A cut-off within each dimension to determine whether the person is deprived in that dimension;

b) A cut-off across dimensions that identifies the poor counting the number of dimensions in which a person is deprived.

The index is aggregated through Foster-Greer-Thorbecke (FGT) measures adjusted for multidimensionality.

5. Integrated Assessment Analysis: identification of the primary drivers for environmental changes in the study area; analysis of the human well-being - ecosystem links through the six classes of instrumental freedoms; analyse of trade-offs or synergies among the services provided by ecosystems underpinned by local biodiversity and the various constituents of well-being. Assess the implications for biodiversity conservation and human well-being.

6. Policy implications: discussion of the human well-being – ecosystem linkages in order to draw policy implications and suggest intervention strategies.

Expected Results

The underlying assumption to this research is that an integrated approach is needed to understand biodiversity and ecosystem services in terms that are meaningful to the people that depend on them. This research aims therefore to contribute to the development of this integrated approach through a socio-ecological model and to bring new understanding on how human dynamics intersect with nature in a multifaceted and complex way. It follows the path stressed by the Convention of Biological Diversity of stopping to separate environmental sustainability from development, and does so by understanding the links that make the conservation of agro-biodiversity and ecosystem services potential instruments of development. In this view both human well-being and sustainable resource use can be promoted by highlighting the synergies between them. Because many dimensions of the human well-being – environment nexus are non commensurable, this research shows the usefulness of applying multidimensional indicators against monetary indicators, which overlook important information and might not capture the socio-ecological interactions that happen in reality.

This research also contributes to the operationalization of the Capability-Ecosystem Approach by applying and testing it on a local scale and through the introduction of an analysis of the role of agro-biodiversity in providing ecosystem services that influence human well-being. Our focus is therefore in line with the growing agreement that there is a strong need for more research on the local scale on the way ecosystem services influence human well-being, especially in terms of regulating and cultural services (Duraiappah 2011; Raudsepp-Hearne, 2010, 2011; Nelson 2011).

Through exploring and assessing the socio-economic implications of agro-biodiversity use and conservation we also aim at informing concrete policies and public management decisions relevant to the Mayan communities that depend on local agro-biodiversity in the Yucatan rural areas. By applying a level of analysis focused on the local scale this research gives insights on the type and relevance of the relationship between agro-biodiversity and human well-being in the area. This will be useful to deepen knowledge on the direct and indirect drivers of change at the local level and to derive relevant policy implications. Moreover, by understanding how natural capital delivers ecosystem services relevant to human well-being important lessons can be derived to improve policy sustainability and its ability to address local problems in a way significant to the people affected, considering their culture and traditional knowledge. Finally, the understanding of the use and relative value of ecosystem services and biodiversity to different groups in society can help improve the design of incentive mechanisms for the efficient provision and use of these ecosystem services.

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