Economics of Land Degradation Initiative: Methods and Approach for Global and National Assessments

(Basic standards for comparable assessments)

DRAFT FOR DISCUSSION

Ephraim Nkonya#, Joachim von Braun*, Alisher Mirzabaev*, Quang Bao Le^, Ho Young Kwon#, Edward Kato#, Oliver Kirui* and Nicolas Gerber*

*Center for Development Research (ZEF), University of Bonn
#The International Food Policy Research Institute (IFPRI)
^Swiss Federal Institute of Technology (ETH) Zurich

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Ephraim Nkonya, Joachim von Braun, Alisher Mirzabaev, Bao Quang Le, Ho Young Kwon, Kato Edward, Oliver Kirui and Nicolas Gerber

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List of Abbreviations

AVHRR	Advanced Very High Resolution Radiometer
BMZ	German Federal Ministry for Economic Cooperation and Development
ELD	Economics of Land Degradation
EU	European Union
FAO	United Nation's Food and Agriculture Organization
GDP	Gross domestic product
GIMMS	Global Inventory Modeling and Mapping Studies
GIS	Geographic Information System
IFPRI	International Center for Food Policy Research
NDVI	Normalized Differenced Vegetation Index
NGO	Non-Governmental Organization
NENA	Near East and North Africa
NOAA	U.S. National Oceanic and Atmospheric Association
NPP	Net Primary Production
PES	Payment for Ecosystem Services
SSA	Sub-Saharan Africa
SLM	Sustainable Land Management
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Program
USD	United States Dollars
USDA-NRCS	United States Department of Agriculture, Natural Resources Conservation Service
TEV	Total Economic Value
ZEF	Center for Development Research, University of Bonn

Introduction and Problem Definition

Purpose

The purpose of this paper is to provide sound and feasible standards for a national and global assessment approach of the economics of land degradation. Only if some basic standards are identified and adhered to, comparative assessment between countries and useful aggregation of findings based on case studies can be achieved. This is quite important to impact on policy for investment and land use, and to get land and soil degradation problems out of their current obscurity. The key objective of this global Economics of Land Degradation (ELD) assessment is, therefore, to provide a comprehensive, consistent and feasible framework for guiding comparable national/regional ELD case studies that support policy actions to combat land degradation. The presented paper also seeks to raise international awareness about the need to compare multi-dimensional degradation costs between the scenarios of action and inaction against land degradation as the basis for creating incentive for social combating of land degradation. The formulation of a desirable ELD assessment framework and its implementation involve the answering of the following scientific questions:

i) What are key drivers of land degradation across typical social-ecological regions of the world?

ii) What are the economic, social and environmental costs of land degradation and net benefits resulting from taking actions against degradation compared to inaction against the phenomenon?

iii) What are the feasible policy and development strategies that enable and catalyze SLM actions?

This paper proposes analytic concepts and methods to collect and analyze data to answer the above questions regarding ELD at national and global levels.

The paper identifies minimum standards that need to be adhered to in all country case studies to deliver comparable material for international assessment and ELD policy guidance. It also identifies additional and desirable areas of information and analyses that would add value to country case study material. However, there are tradeoffs between level of investment, sophistication, and timely material that can prompt action soon. It should also be pointed out, that with this framework for assessments it is not implied that there may not be many other useful study approaches to address land and soil degradation. The ELD approach, however, needs to follow a few criteria and principles to ultimately add up to useful economic insights. The approaches presented here build further and implements the analytical framework of economics of land degradation (ELD) proposed by Nkonya et al. (2011), by also incorporating the feedback received so far from various stakeholders. Those readers who are interested in getting more information on the review of previous literature on economic assessment of land degradation, the detailed conceptual framework proposed for the global ELD assessment, and an overall background of this ELD research are referred to Nkonya et al. (2011) and von Braun et al. (2012).

Problem Definition

Healthy soils - which are productive and able to meet their ecosystem functions - are essential for sustainable development, including food security and improved livelihoods. In spite of this, the key ecosystem services provided by soils have usually been taken for granted and their true value – beyond market value – is being underrated (von Braun et al. 2012). This pattern of undervaluation of soils is about to change in view of rapidly rising land prices, which is the result of increased shortage of land and high output prices (ibid.). Moreover, the value of soil-related ecosystems services is being better understood and increasingly valued. Globally, it is estimated that about a quarter of land area is degraded, affecting more than a billion people all over the world (Lal et al. 2012). Land degradation has its highest toll on the livelihoods and well-being of the poorest households in the rural areas of developing countries (Nachtergaele et al. 2010). Vicious circles of poverty and land degradation, as well as transmission effects from rural poverty and food insecurity to national economies, critically hamper their development process.

Despite the urgent need for preventing and reversing land degradation, the problem has yet to be appropriately addressed (Lal et al. 2012). Policy actions for sustainable land management (SLM) are lacking, and a policy framework for action is missing (Nkonya et al. 2011). Such a framework for policy action needs to be supported by evidence-based and action-oriented research (von Braun et al. 2013). In this regard, previous studies on assessing economic impacts of land degradation have played a useful role in highlighting land degradation as a globally profound issue. However, most of them focused exclusively on the reduction in crop yields and carbon sequestration potentials due to soil degradation, without comprehensive accounting for economic value of other losses across a wide range of land ecosystem services (Nkonya et al. 2011). These losses include not only environmental degradation cost measured directly on-site (e.g., soil loss and nutrient depletion), but also the cost of indirect and off-site environmental impacts (e.g., siltation of water bodies, water pollution, and biodiversity declines) (Foley et al. 2005). Moreover, past land degradation economic assessments were limited to agricultural production despite tangible deep impacts of the phenomenon on essential aspects of sustainable development such as food security and national welfare (ibid.). Furthermore, past studies at regional or local scales used different assessment methods that cause difficulties in comparative analyses needed for generalization of impact patterns.

This action-oriented focus and the definitions of land and land degradation determine the methodological approaches of the ELD analysis. United Nations Convention to Combat Desertification (UNCCD) (1996) defines land as a terrestrial ecosystem consisting of flora, fauna, hydrological processes and other ecological services beneficial to human beings. The Millennium Ecosystem Assessment (MA 2005) defines land degradation as long-term loss of on-site and off-site terrestrial ecosystem goods and services, which humans derive from them. These definitions lead to using a comprehensive approach which takes into account both short- and long-term direct and indirect, on-site and off-site benefits of sustainable land management versus the related costs of land degradation. Thus, to be comprehensive, this economic assessment uses Total Economic Value (TEV) approach, which assigns value to all use and non-use ecosystem services (see conceptual framework below). Consequently, we strive to capture all changes, both degradation and improvement, in ecosystem functions and services attributed to land ecosystems.

The action against land degradation involves preventing the degradation of using/usable lands or rehabilitating degraded lands. We refer to action against land degradation as sustainable land management (SLM), which – according to TerrAfrica (2006) – is defined as the "adoption of land systems that, through appropriate management practices, enables land users to maximize the economic and social benefits from the land, while maintaining or enhancing the ecological support functions of the land resources." In this study, we define "actions against land degradation" as land management which leads to persistent improvement of biological productivity and biodiversity of the land. This improvement is generally recognized as being closely determined by the increasing of net primary productivity (NPP) of the land, under certain conditions, and the improvement of soil fertility. The NPP trend, approximated by the trend of inter-annual Normalized Difference Vegetation Index (NDVI), can be an indirect indicator of soil degradation or soil improvement if the nutrient source for vegetation/crop growth is *solely*, or *largely*, from the soils (i.e., soil-based biomass productivity). In the agricultural areas with intensive application of mineral fertilizers (i.e. fertilizer-based crop productivity), NPP trend (via NDVI trend) principally cannot be a reliable indicator of soil fertility trend (Le 2012a). In this case, alternative indicators of soil fertility should be used. Moreover, the elevated levels of CO_2 and NOx in the atmosphere (Reay et al. 2008) can cause a divergence between NPP trend and soil fertility change as the atmospheric fertilization effect has not been substantially mediated through the soil. The rising level of atmospheric CO_2 stimulates photosynthesis in plants' leaves, thus increasing NPP, but the soil fertility may not necessarily be proportional with the above ground biomass improvement. The wet deposition of reactive nitrogen and other nutrients may affect positively plant growths as foliate fertilization without significantly contributing to the soil nutrient pool, or compensating nutrient losses by soil leaching and erosion. The correction of the masking effect of atmospheric fertilization can be done by considering the quantum of biomass improvement in intact vegetation area, using the method proposed in Vlek et al. (2010) and Le et al. (2012b). However the result must be evaluated by comparing the spatial corrected NDVI trend pattern with independent indicators, such as NPP or soil erosion calculated by different data and models (e.g. Le et al., 2012).

Conceptual Framework
Land Degradation and Total Economic Value

The Total Economic Value (TEV) approach is required to capture the comprehensive definition of land degradation. TEV includes use value, which is further divided into direct and indirect use (Figure 1). The direct use includes provisioning services, which involves extractive consumption (e.g. crop production) while indirect use value includes ecosystem functions such as water purification, carbon sequestration, etc. Use value also includes option value, which is value of an ecosystem services for future direct or indirect use. Non-use value is divided into bequest and existence value, both of which are hard to measure since they are not traded in the market. An additional challenge of measuring TEV is the potential of double-counting, in which ecosystems services, whose ecological functions may not be split up into particular benefits that can be valued and then aggregated (Balmford et al. 2008). Care will be taken to avoid double counting.

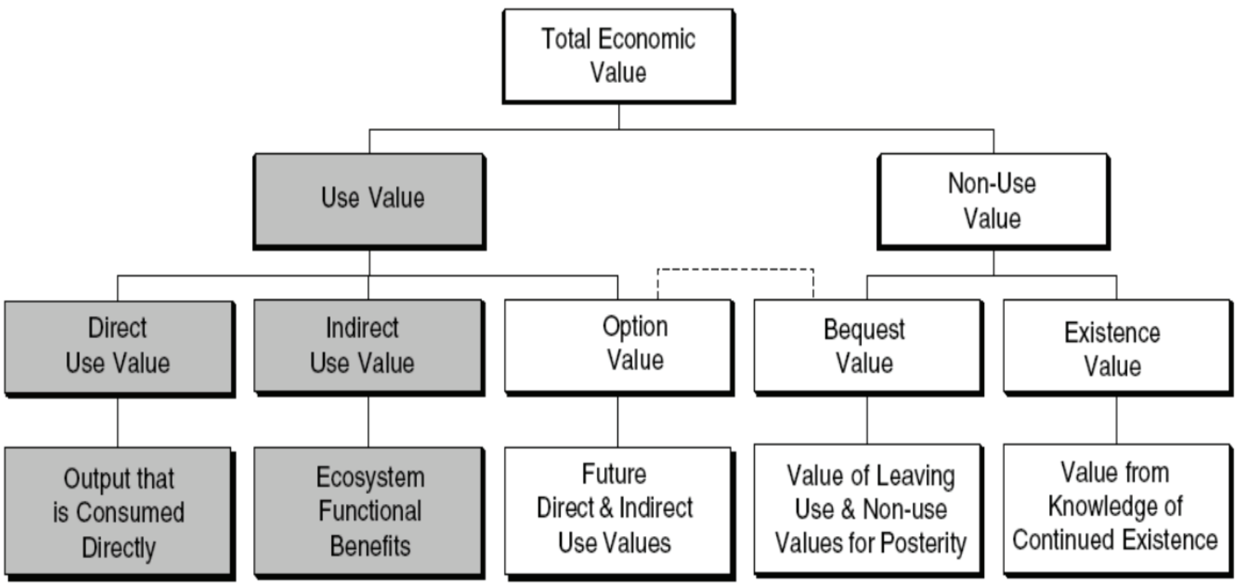

Figure 2: Total Economic Value

Source: Turner et al (1994)

The ELD conceptual framework is based on comparing the costs of action against land degradation versus the costs of inaction (Figure 2). The causes of land degradation are divided into proximate and underlying, which interact with each other to result in different levels of land degradation. Proximate causes of land degradation are those that have a direct effect on the terrestrial ecosystem. The proximate causes are further divided into biophysical proximate causes (natural) and unsustainable land management practices (anthropogenic). The underlying causes of land degradation are those that indirectly affect the proximate causes of land degradation, such as institutional, socio-economic and policy factors. For example, poverty could lead to the failure of land users to invest in sustainable land management practices leading to land degradation.

The level of land degradation determines its outcomes or effects - whether on-site or offsite - on the provision of ecosystem services and the benefits humans derive from those services. Actors can then take action to control the causes of land degradation, its level, or its effects.

Many of the services provided by ecosystems are not traded in markets, so the different actors do not pay for negative or positive effects on those ecosystems. The value of such externalities is not considered in the farmer's land use decision, which leads to an undervaluation of land and its provision of ecosystem services. The ecosystem services should be considered as capital assets, or natural capital (Daily et al. 2011). This natural capital should be properly valuated and managed as any other form of capital assets (Daily et al. 2000). The failure to capture these values for land ecosystems causes higher rates of land degradation. To adequately account for ecosystem services in decision making, the economic values of those services have to be determined. There exist various methods to evaluate ecosystem services (Nkonya et al. 2011), however, attributing economic values to ecosystem services is challenging, due to many unknowns and actual measurement constraints. The valuation of the natural capital, therefore, should follow three stages (Daily et al. 2000): i) evaluation of alternative options, for example, degrading soil ecosystem services vs their sustainable management, ii) measurement and identification of costs and benefits for each alternative, and iii) comparison of costs and benefits of each of the alternatives including their long-term effects (ibid.). However, identifying and aggregating individual preferences and attached values to ecosystem services, including over time, for each alternative option, is not a straightforward task (ibid.) As economic values are linked to the number of (human) beneficiaries and the socioeconomic context, these services depend on local or regional conditions. This dependence contributes to the variability of the values (TEEB 2010).

The green square box in Figure 2 deals with the economic analysis that is carried out, and the green arrow shows the flow of information that is necessary to perform the different elements of the global economic analysis. Ideally, all indirect and off-site effects should be accounted for in the economic analysis to ensure that the assessment is from society's point of view and includes all existing externalities, in addition to the private costs that are usually considered when individuals decide on land use. Similarly, actions against land degradation have direct benefits and costs - the costs of specific measures and economy-wide indirect effects - that is, opportunity costs. In other words, resources devoted for these actions cannot be used elsewhere. Thus, mobilizing those resources to prevent or mitigate land degradation affects other sectors of the economy as well.

This assessment has to be conducted at the margin, which means that costs of small changes in the level of land degradation, which may accumulate over time, have to be identified. Bringing together the different cost and value types to fully assess total costs and benefits over time and their interactions can be done within the framework of cost–benefit analysis and mathematical modeling. In doing this, care should be taken in the choice of the discount rates because the size of the discount rate, as well as the length of the considered time horizon, can radically change the results. Discount rates relate to people's time preferences, with higher discount rates indicating a strong time preference and attaching a higher value to each unit of the natural resource that is consumed now rather than in the future.

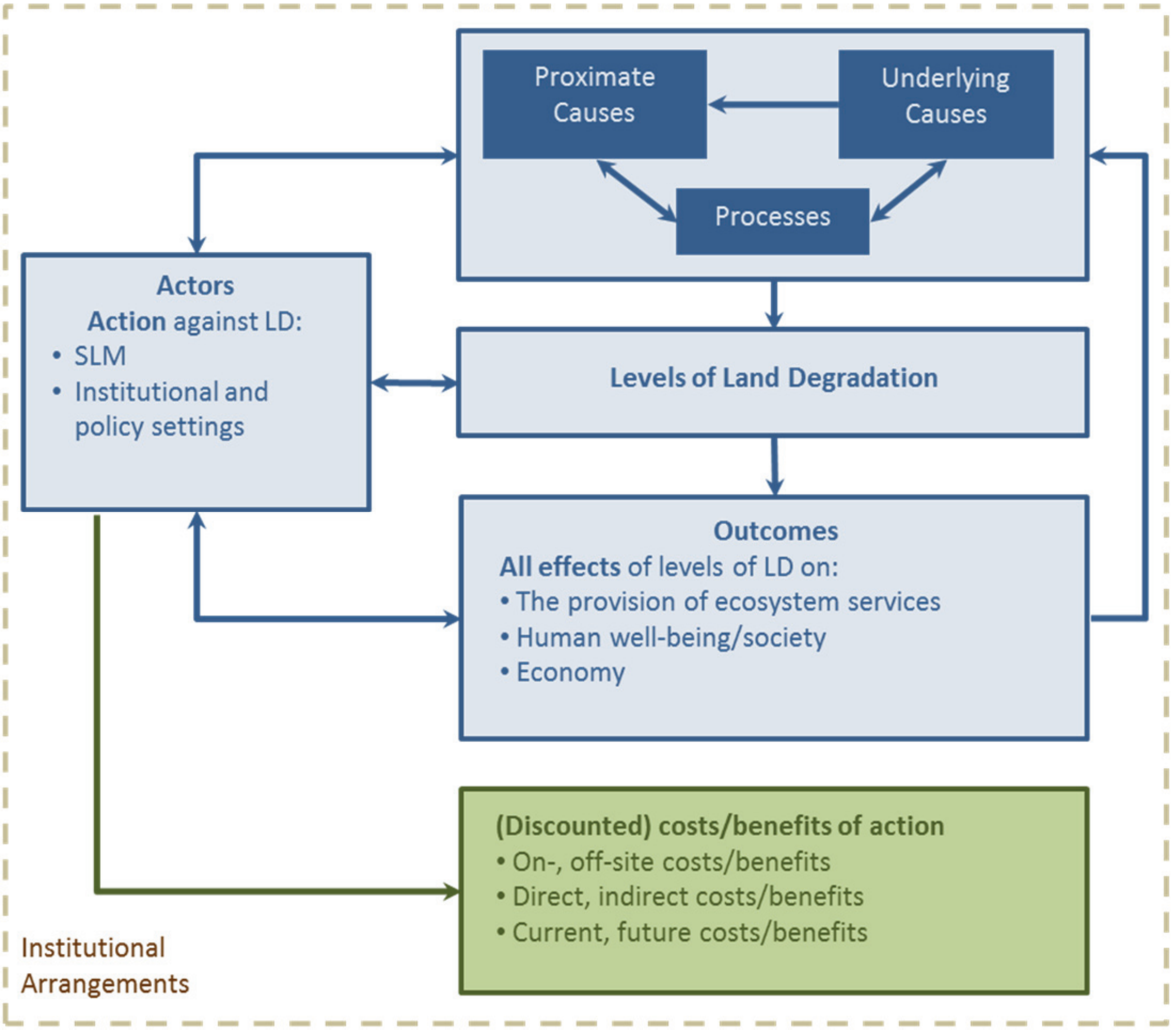

Figure 2. The Conceptual Framework of ELD Assessment – Action Scenario
Source: adapted from Nkonya et al. (2011)

Institutional arrangements, or the "rules of the game" that determine whether actors choose to act against land degradation and whether the level or type of action undertaken will effectively reduce or halt land degradation, are represented as dotted lines encapsulating the different elements of the conceptual framework. It is crucial to identify and understand these institutional arrangements in order to devise sustainable and efficient policies to combat land degradation. For example, if farmers over-irrigate, leading to salinization of the land, it must be understood why they do so. As an illustration, it may be that institutional arrangements, also referred to as distorting incentive structures, make it economically profitable for farmers to produce as much crops as possible. Missing or very low prices of irrigation water in irrigation schemes act as such an incentive in a misleading institutional setup.

Finally, it is also essential for the analysis to identify all the important actors of land degradation, such as land users, landowners, governmental authorities, and industries, as well as identify how institutions and policies influence those actors. Transaction costs and collective versus market and state actions are to be considered. In general, the institutional economics is particularly important in the assessment of land degradation when it comes to the definition and design of appropriate actions against land degradation, as well as of the inaction scenarios serving as a benchmark.

Sampling Framework for Case Studies

It has been demonstrated ealier that proximate and underlying drivers of land degradation are intricately embedded in their specific local contexts (Nkonya et al., 2011, von Braun et al. 2013), and hence, only through comprehensive analysis of these local heterogeneous interactions that meaningful insights could be derived about causes and necessary actions against land degradation. On the other hand, needless to say that these insights should not be exclusively limited only to some specific local settings, but should have a global relevance. In this regard, case study methodology is the preferred choice of method when the phenomenon being studied is indistuinguishable from its context (Yin 2003) - which enables to achieve the first objective of local thoroughness. The second objective of global relevance is achieved by designing a rigorous sampling framework with theoretically sound case study selection strategy.

Extrapolation of case study findings beyond these case studies themselves is possible only when the case study design has been based on theoretical grounds: where specific research questions are asked to test the validity of rival explanations of cause-and-effect relationships in land degradation (von Braun et al, 2012; Table 1 on causes of land degradation). Carefully selected multiple case studies are the means to provide a more convincing test of a theory and specify conditions under which different, perhaps even opposing, theories could be valid (de Vaus, 2001). Moreover, the external validity of a case study depends on its capacity for theoretical generalization, rather than statistical generalization which is conducted through probability-based random sampling techniques. In that sense, case studies are like experiments with replications: if the theoretical insights gained from case studies conducted in multiple settings coincide, then the potential of external validity of these results is higher. To achieve such external validity, case studies are selected not statistically, but "strategically" (ibid.), which necessitates selecting those cases which will enable to rigorously test the causal relationships in different contexts (ibid.). Random probability based selection of countries may not be the best approach in this context, since this aproach will allocate similar likelihood of being selected to each country irrespective of its biophysical heterogeneity, population size or economic importance – which may, in fact, provide with distorted global estimates. Finally, it is essential that the core research methodologies and protocols in each of the case studies should be similar for ensuring comparibility of their results.

For conducting this global economic analysis of land degradation, case study countries have been carefully selected based on purposive sampling framework, based on maximum variation approach, where it was sought to comprehensively capture a wide spectrum of heterogeneous contexts of land degradation in order to test rival cause-and-effect hypotheses about land degradation. Thus, the main objective in the sampling was to ensure the external validity and global relevance of the selected case study countries for a big heterogeneity of land degradation, institutional and socio-economic situations around the world.

The sampling strategy consisted of three steps.

First, earlier analyses of drivers of land degradation has identified such key socio-economic and institutional underlying factors of land degradation as GDP per capita, population density, government effectiveness and agricultural intensification (Nkonya et al. 2011). Based on these characteristics, the countries of the world have been clusterd using K-means clustering tecnique into seven clusters with more homogenous within-cluster characteristics. The decision on the optimal number of clusters was guided both by the results of the formal statistical Calinsky-Harabasz stopping rule (Calinsky and Harabasz, 1974) [1] , and graphical and numerical exploratory analysis of the data.

Second, the selected clusters were formally validated against several key socio-economic and biophysical variables, which were not part of the inital clustering, such as long-term changes in remotely-sensed NDVI values (Tucker et al. 2004), which can be used as a potential proxy for land degradation, share of rural population in the total, share of agriculture in GDP, average cereal yields per hectare. The identfied clusters showed significant differences for each of these variables, thus providing a strong evidence for the validity of the clustering approach employed (Table 1. Figure 3).

Third, once the countries have been put through these selection filters to ensure their representativeness of global heterogeneity in terms of socio-economic, institutional and land degradation characteristcis, countries were selected from each cluster for in-depth case studies, based on such additional ciriteria as i) regional representativeness, ii) the selected countries have collected or are collecting data required for the ELD assessment.

This selection of countries is highly and sufficiently heterogeneous in terms of both biophysical, socio-economic and institutional characteristics to enable rigourous ground-level testing of various causal hypotheses about drivers of land degradation, and for specifying which causal relationships could be prevailing under each of these different interactions of factors (see Section on *Drivers of Land Degradation* below). The representativeness of the case study countries is also demonstrated by their good coverage of the farming systems typologies (Annex 1). Moreover, these globally representative case studies also allow for achieving our objective of providing national and global-level estimates of costs of land degradation and net benefits of taking action against it through sustainable land management investments and policies (see section on *Cost and benefits of action vs inaction against land degradation* below).

In-depth case studies are planned to be conducted in 11 of these case study countries (hihglighted in yellow), while second-tier case studies will be conducted in the remaining nine countries (highlighted in blue), even though in less intensive level and exclusively based on already available data, namely, spatial GIS data, existing household surveys, and secondary statistics at district level (Table 2). Given higher levels of development challenges and opportunities posed by land degradation impacts, Cluster 1 countries are given higher weight in this particular selection. Naturally, the more is the number of case study countries, the higher is the accuracy of extrapolation – so depending on time and budgetary constraints, efforts will be made to include as many of these additonal countries in the in-depth analysis, but also, to further increase the number of case study countries. What is important, this framework can provide a consistent conceptual basis for adding more case studies from around the world for the comparable ELD assessment.

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[1] Milligan and Cooper (1985) conclude, using a Monte Carlo simulation, that Calinsky-Harabasz stopping rule provides the best results among the 30 stopping rules they have compared.

Table 1. Clustering and validation results

Clusters	GDP per capita	Government effectiveness	Population density	Agricultural Intensification	Maximum changes in NDVI values between the baseline (1982-84) and endline (2003-06)*	Cereal yields	Share of Agriculture in GDP	Share of Rural Population in Total
1	lower	lower	Higher	lower	Highest dispersion, both biggest decreases and increases	lower	higher	higher
2	mid	mid	Higher	higher	smaller decreases	mid	mid	higher
3	mid	mid	Higher	mid	smaller decreases	mid	mid	mid
4	mid	mid	Lower	mid	larger decreases	mid	mid	lower
5	mid	mid	Lower	lower	smaller decreases	lower	mid	mid
6	higher	higher	Mid	higher	larger decreases	mid	mid	lower
7	higher	higher	Higher	higher	smaller decreases	higher	lower	lower

Notes:
i) For easy reading of color patterns: cells expected to show strong negative association with land degradation, or being strongly negatively affected by land degradation are colored in red. Similarly, medium and lower levels are depicted with brown and green colors, respectively.

* The NDVI time-series comes from GIMMS dataset, which is driven from NOAA AVHRR satellite data (http://glcf.umd.edu/). The NDVI changes here-calculated have not been corrected for the effects of inter-annual rainfall variation, atmospheric fertilization and human application of mineral fertilizer. Appropriate analysis of inter-annual NDVI trend with the consideration of these effects (e.g. Vlek, Tamene and Le, 2010) will be done as a part of this ELD research.

Table 2: Tentative case study countries and regions (in-depth case studies highlighted in yellow)

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Ethiopia	China	Turkey	Argentina	Bhutan	Colombia	Germany
Kenya	India	Uzbekistan	Peru	Russia		USA
Nigeria	Egypt	Morocco				
Senegal						
Niger						
Tanzania						
Zambia						

Sub-Saharan Africa	North Africa and Near East	Asia	Latin America	Europe and North America
Ethiopia	Turkey	Bhutan	Argentina	Germany
Kenya	Egypt	China	Peru	USA
Niger	Morocco	India	Colombia	
Nigeria		Uzbekistan		
Senegal				
Tanzania				
Zambia				

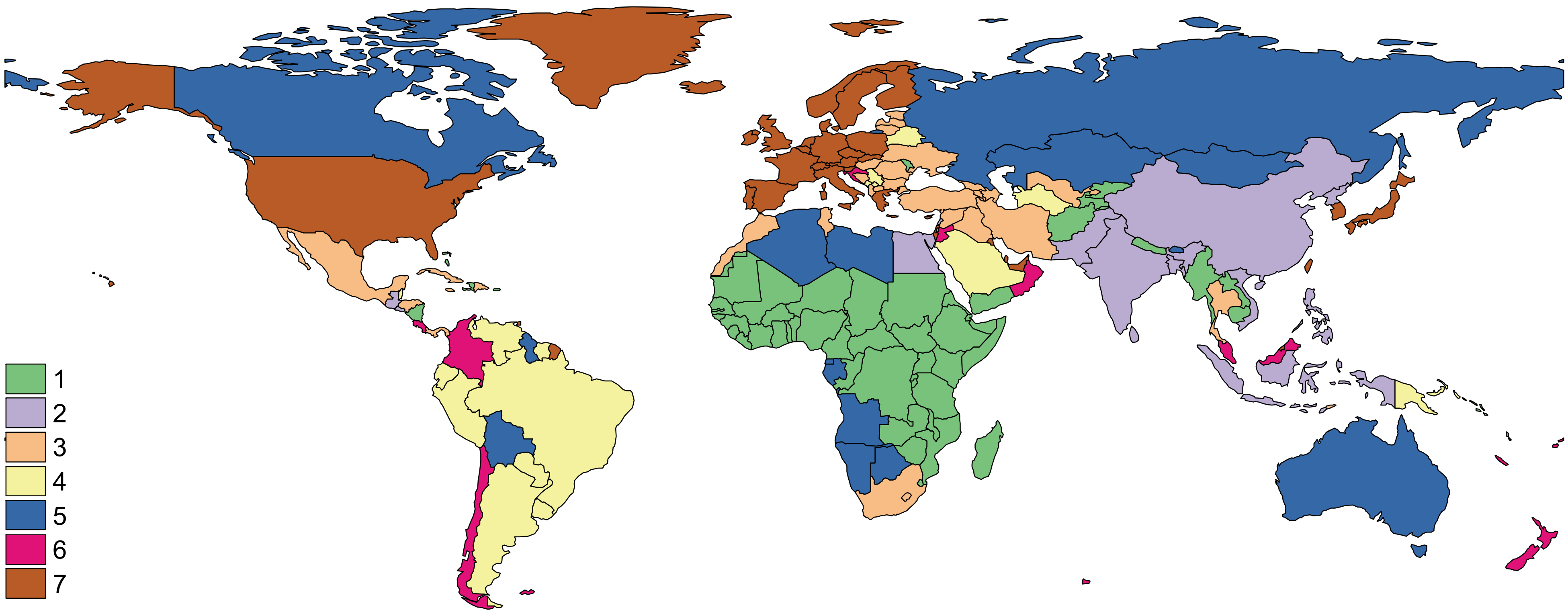

Figure 3. Global Map showing clustering results

Following this sampling framework, and using the European Joint Research Center (JRC) guidelines (Toth et al. 2012), the data collected from the case study countries will be interpolated across the corresponding farming systems within the same cluster or the same region. The global map of farming system zones (Dixon et al. 2001) – defined as farm systems with similar resource and enterprise patterns, household livelihoods and constraints, and which are likely to have to similar development pathways – will be used. This is appropriate because the global farming system zones show strata of social-ecological factors that are consistent with potential drivers of land degradation as summarized in von Braun et al. (2012). Hence interpolation of case studies' results along farming systems is likely to produce results which reflect the major drivers of land degradation. No interpolation will be made across regions. For example, no data from Sub-Saharan Africa will be interpolated to Latin America or Asia.

Empirical Research Framework

The empirical research framework adopted by this ELD assessment consists of three mutually reinforcing categories:

1. **Core ELD research methods:** standard research methods to be applied in all case studies to fulfill the minimum methodological requirements for globally comparable and rigorous ELD assessment,
2. **Desirable ELD approaches**: methods that do not need to be exactly similar and standard in all case study countries, but are highly desirable to be applied, in locally appropriate forms, seeking to address the key challenges specific in each context. They will seek to complement, cross-validate and triangulate, in general, test the robustness of the results obtained from the core research by using alternative methods or datasets and/or provide more detailed analysis of some specific aspects and impacts of land degradation and sustainable land management.
3. **Sophisticated ELD methods** for expanding the research frontiers in ELD research. They aim to build and expand on the cutting-edge of interdisciplinary land degradation research.

Table 3. Examples of three categories of ELD research

Core	Desirable	Sophisticated
Descriptive and econometric analysis of drivers of land degradation	Detailed analyses of poverty-land degradation, food security-land degradation interactions	Game theoretic and experimental economics approaches for assessing household risk attitudes, key factors of SLM adoption
	Drivers of SLM adoption	Field assessments of the value of ecosystem services
Bio-economic modeling of action vs inaction against land degradation, including simulation of selected institutional and policy options for addressing land degradation	Triangulation of different crop modeling approaches within the bio-economic modeling	The use of mobile communications and ICT tools for identification /groundtruthing of land degradation
	Inter-sectoral effects of land degradation beyond agriculture within general equilibrium analyses	Integrated application of high resolution remote sensing and GIS together with economic analysis using spatial econometric methods
	More to be added in consultation with partners and stakeholders	More to be added in consultation with partners and stakeholders

Analytical approaches

Descriptive analysis of drivers of land degradation

As the start to the empirical work, an exploratory analysis would be conducted for better understanding the characteristics and trends in land degradation, the interaction of proximate and underlying causes of land degradation and other relevant socio-economic data. This exploratory analysis will also be used for refining the hypotheses about the drivers of land degradation, which will be later tested using the in-depth data from the case study countries. The exploratory analysis will be done using simple descriptive tools, while the results will be illustrated using maps, figures and tables. For example, correlation between poverty, government effectiveness, land tenure, environmental policies and other key drivers of land degradation will be overlaid with a change in NDVI or other relevant land degradation indicators. This will form useful and simple patterns to be used to enrich the econometric results. For example, data on land tenure (Figure 5) will be overlaid with change in NDVI to show areas where NDVI decreased (possible land degradation) or increased (possible land improvement) while such areas had secure land tenure or insecure land tenure.

Drivers of Land Degradation

Even when taking action against land degradation is economically justified, some land users may not do so due to other constraints such as lack of access to credit or product markets, but also due to their risk attitudes. Risk-averse farmers may not necessarily adopt SLM even when they are profitable. Hence it is important to analyze the drivers of land degradation and adoption of sustainable land management practices in order to identify policies for increasing SLM adoption.

Therefore, the proximate and underlying causes of land degradation will be analyzed at three levels.

(i) *Global at pixel level*. Like in Nkonya et al (2011), a pixel-level estimation of drivers of land degradation will be made. However, this study will improve on the Nkonya et al (2011) by using more recent data and controlling for more drivers of land degradation (see Table 3). Moreover, NDVI values used in this analysis will be corrected for the effects of fertilization that has been shown dissimulate land degradation (Vlek et al. 2010). A structural model will be estimated – and as far as availability of instrumental variables (IV) permits, a two-stage least square (2SLS) model will be applied to address potential endogeneity biases.

(ii) District level in case study countries. Contingent on data availability in the case study countries, a panel data at district level will be formed to analyze the land degradation drivers at district level. Available data on severity of poverty and household surveys with a large number of variables are shown in Table 3. Since most of these data are cross-sectional, they will be aggregated at district level to form a panel.

(iii) Household level analysis in the case study countries with panel household data. Using land use change as an indicator of land degradation, a panel data will be used in those countries, where panel data of land use change are available (Table 3).

Following Meyfroidt et al (2010); Lambin (2001); Lambin and Geist (2006) and Nkonya et al (2011**), the structural first difference model estimating drivers of land degradation or land improvement at global/regional, district and household levels,** using annualized data is:

$$\Delta \text{ NDVI} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}\Delta \boldsymbol{x_1} + \boldsymbol{\beta_2}\Delta \boldsymbol{x_2} + \boldsymbol{\beta_3}\Delta \boldsymbol{x_3} + \boldsymbol{\beta_4}\Delta \boldsymbol{x_4} + \boldsymbol{\beta_5}\Delta \boldsymbol{z_i} + \boldsymbol{\varepsilon_i} \qquad \textbf{(1)}$$

where,

$\mathbf{x_1}$ = a vector of biophysical causes of land degradation (e.g. climate conditions, topography, soil constraints);

$\mathbf{x_2}$ = a vector of policy-related, institutional, demographic and socio-economic causes of land degradation (e.g. population density and growth rate, urban growth, GDP per capita, agricultural intensification and growth, national, international policies directly affecting land management, government effectiveness, land tenure, etc);

$\mathbf{x_3}$ = a vector of variables representing access to rural services (e.g. links to extension services, road proximity or density, access to information, assess to rural credits);

$\mathbf{x_4}$ = vector of variables representing rural household level capital endowment, level of education, poverty level, physical capital, social capital;

$\mathbf{z_i}$ = vector of fixed effect variables, including administrative divisions (region, NDVI prior to the baseline period, etc).

Like the case of the returns to land management practices shown above, the variables will be aggregated to obtain panel data at district and global level, but with adjustments reflecting data availability and relevance.

The use of NDVI or other satellite-derived measures as proxies of land degradation may occasionally lead to less accurate results as NDVI or other satellite-derived indicators may not be fully collinear with land degradation processes on the ground. For example, NDVI cannot easily differentiate between composition changes in vegetation, hence can lead to misleading conclusions when secondary salinization leads to abandonment of previously agricultural areas and replacement of agricultural crops by halophytic weed plants. To minimize such inaccuracies, ground-truthing of satellite-derived data will be conducted in close cooperation with local partners, whenever appropriate through the use of innovative crowd-sourcing approaches involving the use of mobile communications.

Moreover, the above analysis will be further enriched through more **detailed research into the poverty-land degradation, food security-land degradation interactions** – to better estimate the impact of land degradation on the livelihoods and food security of poor households with the aim to identify SLM measures and policies that could also decrease poverty rates and enhance food security.

Furthermore, studies will be conducted to capture the **risk attitudes** of surveyed households in terms of adopting sustainable land management practices through use of **economic experiments**, where key factors shaping these risk attitudes and household SLM behavior will also be identified.

Whenever household-level data on **SLM adoption** is available, they will be used, **within multinomial choice model** frameworks, along with a set of corresponding household-specific socio-economic, demographic, farm production, institutional and other variables, in order to identify key factors leading or constraining the adoption of SLM practices.

Cost and benefits of action vs inaction against land degradation

Since we follow the broad definition of land degradation which captures the on-site and off-site effects of land management, we use social costs and benefits of land degradation. The social cost and benefit of action against land degradation and inaction is given by the net present value (NPV) for taking action against land degradation in year t for the land users planning horizon T:

$$\pi^c_{t\,t} = \frac{1}{\rho^t}\sum_{t=0}^{T}(PY^c_t + IV_t + NU_t + b^c_t - lm^c_t - c^c_t - \tau^c_t) \quad \textbf{(2)}$$

Where π_t = NPV; Y^c_t= production of direct use provisioning services when using SLM practices; P= unit price of Y^c_t; IV_t = indirect use value; NU_t = on-site non-use value; b^c_t = off-site positive benefit of SLM practices ρ^t = 1+r, r = land user's discount rate; lm^c_t = cost of SLM practices; c^c_t = direct costs of production other than land management; τ^c_t = off-site costs of SLM – including use and non-use costs. The term τ^c_t implies that even SLM could produce negative off-site costs. For example, application of chemical fertilizer leads to greenhouse gas (GHG) emission. One kg of nitrogen requires about 3 kg of CO_2-eq (Vlek et al., 2004) because of the high energy requirement for the manufacture and transport of fertilizer and the related CO_2 emissions.

If land user does not take action against land degradation, the corresponding NPV is given by

$$\pi^d_t = \frac{1}{\rho^t}\sum_{t=0}^{T}\left(PY^d_t + IV_t + NU_t + b^d_t - lm^d_t - c^d_t - \tau^d_t\right) \quad \textbf{(3)}$$

Where π^d_t = NPV when land user uses land degrading practices. All other variables are as defined in above but with superscript d indicating land degrading practices.

The benefit of taking action against land degradation is given by $BA = \pi^c_t - \pi^d_t$

The difference $\pi^c_t - \pi^d_t$ plays an important role in land users' decision making during their planning horizon T. **Error! Reference source not found.** summarizes the actions of land users when returns to SLM is smaller, greater or equal to the corresponding returns to SLM. If the returns to land management for the SLM are smaller than the corresponding returns for land degrading practices, the land user is likely to use land degrading practices.

Table 4: Action vs inaction decisions at different levels

$\pi^c_t - \pi^d_t$	Logical action/inaction
> 0	Take action against LD
< 0	Don't take action. Alternatively provide incentives to take action against land degradation (e.g. PES*)
= 0	Indifferent, hence provide incentives to take action against land degradation (e.g. PES)

NB: Taking action against land degradation include: prevention of land degradation or rehabilitation of degraded lands
*Payment for Ecosystem Services

However, given that prevention of land degradation is expected to be cheaper than rehabilitation of degraded lands, it is always prudent to prevent land degradation. The challenge is internalization of SLM benefits and enhancing adoption of SLM practices for low income farmers who may not have paid to adopt SLM. For example, payment for ecosystem services (PES) could be used when BA ≤ 0 (see **Error! Reference source not found.**). Different policy scenarios will be tested for their impact on land degradation and adoption of SLM technologies. The selection of these policy scenarios will be based on focus group discussions with national and local-level administrators, practitioners and rural communities.

The economic modeling will seek to account for rural households risk attitudes explicitly, based on the findings of the household-level analysis of household risk attitudes indicated in the previous section.

Moreover, this economic modeling will seek to strongly catalyze bottom-up local-level ELD assessment by practitioners, farmers and community groups through providing easy-to-use analytical tools for cost-benefit analysis of adopting SLM options for preventing or/and addressing land degradation.

The analytical work described above will be conducted together with national researchers and practitioners in order to foster a bottom-up approach that will increase the capacity of local institutions to manage lands and to operate on a long-term basis. Moreover, the policy scenarios and recommendations, also developed in close interaction with national researchers, practitioners and farmers, will be articulated in order to promote sustainable land management by promoting the link between bottom-up and top-down approaches, and energizing horizontal and vertical linkages (Figure 4).

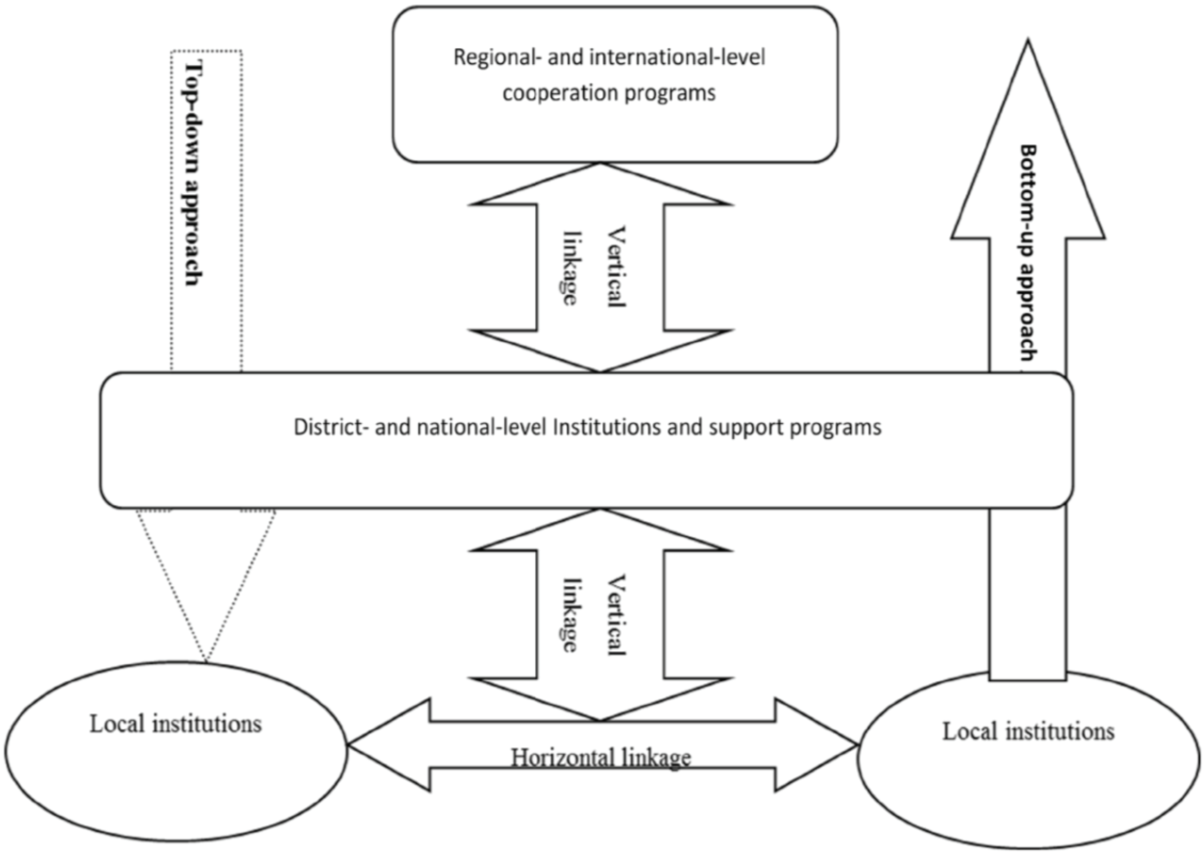

Figure 4. Bottom-up and top-down approaches for SLM

Data

Data for analyzing action and inaction against land degradation

Provisioning services land productivity data *($Y_t^{c,d}$):* Given that land management practices have long-term benefits and costs, time series are required to compute the returns to action/inaction against land degradation. Focus of the land management will be on crops and rangelands, the major land use types with severe land degradation in developing countries. Crop yield simulation models for the major crops are required to obtain Y_t^c and Y_t^d. Crop yield simulation will be done by changing the type of land management practices of lm_t^c and lm_t^d while holding other drivers of land productivity constant. Due to lack of expertise in the research team, data for forests, livestock and other types of major land uses across the globe will be obtained from literature. However, partners and collaborators with expertise in this area will be involved to model other land use types.

In order to calibrate the model, actual experimental data will be collected from research stations in the case study countries. Once model calibrations are done with the actual data, global level crop simulation of major crops (wheat, maize, rice, soybean, and cotton) will be done using IFPRI's rich global change datasets in order to determine the cost of inaction against land degradation,.

Ecosystem functions & services (Indirect value) data: (e.g. value of water purification, nutrient cycling, climate regulation, etc) will be obtained from past studies. In order to fit in the model, the values will be at per hectare basis. A number of publications have estimated the ecosystem functions and services per hectare (e.g. Pearce 2002; Seidl and Moraes, 2000; Pearce 2001; Costanza et al 1997).[2] Moreover, when possible, field assessment will be conducted in the selected case study countries for valuing the ecosystem functions and services.

Non-use value (NU_t): like the case of indirect value data, NU_t will be obtained using past studies from areas with comparable biophysical and socio-economic characteristics. Additionally, some additional data will be collected from the case study countries to verify the NU_t data from literature. Contingent valuation and revealed preference methods will be used.

Off-site benefits and costs and other data: These data will be obtained from literature and from informal interview with key informants in the case study countries.

Data for drivers of LD

Data for determining the drivers of land degradation will be obtained from sources shown Table 5. The table shows the rich data sets currently available. Efforts will be made to obtain better data from the large number of collaborators of this study and from other sources. Given that these data will be at different resolutions and from different sources, method of harmonizing their geographical representations and spatial resolution suggested by Toth et al (2010) will be used.

[2] See also http://www.ecosystemvaluation.org/dollar_based.htm

Table 5. Required data for drivers of land degradation and their availability (global level analysis)

Data	Data source	Web-link/source	Availability	Accessed?
NDVI	GIMMs	http://glcf.umd.edu/data/gimms/	Free	Yes
Global Administrative Borders	GADM	http://www.gadm.org/	Free	Yes
Global soil properties	ISRIC-WISE FAO/IIASA	http://www.isric.org/data/data-download http://www.fao.org/nr/land/soils/harmonized-world-soil-database/soil-quality-for-crop-production/en/	Free	Yes
Africa soil information – Geo-referenced data on Land Degradation Surveillance	AFSIS	http://www.africasoils.net/	Free	No
Biodiversity	PBL	Netherlands environmental assessment agency	Free	No
Climate conditions	East Anglia climate research unit	http://www.cru.uea.ac.uk/	Free	Yes
Land management practices	Rate of fertilizer use, conservation agriculture, etc – FAO	FAOSTAT; AQUASTAT		
Topography	Yale Center for Earth Observation (YCEO) Digital elevation model FAO CCIAR-corrected SRTM	http://www.yale.edu/ceo/Documentation/dem.html http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1	Free Free	Yes Yes
Road density		Africa road data http://infrastructureafrica.afdb.org/models/irrigation.asp		
Access to information	Mobile phone coverage	ITU	Free	Yes
Land tenure	WRI – see Figure 3 Land tenure center, University of Wisconsin	http://www.wri.org/map/status-land-tenure-and-property-rights-2005; Land Tenure center, University of Wisconsin	Free	Yes
National policies	Environmental performance index	http://epi.yale.edu/	Free	Yes
Institutions	Government effectiveness	http://www.govindicators.org	Free	Yes
Socio-economic indicators	World Development Indicators	www.worldbank.org	Free	Yes
Population density	CIESIN	http://sedac.ciesin.columbia.edu/data/collection/gpw-v3	Free	Yes

EPI is an Index comprising 25 performance indicators of environmental policies, public health and ecosystem vitality.
Government effectiveness represents quality of public services, civil services, independence from political pressures, policy formulation and implementation, government commitment and credibility to such policies.

A number of variables will be added in the global and regional models estimated in the Nkonya et al (2011). This will improve model estimation and reduce the misspecification bias. The new variables include global soil properties, topography, land tenure, access to information, road density, severity of poverty, and national policies – particularly environmental policies. The dependent variable: NDVI values will be corrected and calibrated to account for the effects of fertilization.

Due to rich data availability, more rigorous analysis will be done in the case study countries using household level data surveys, biophysical characteristics from satellite imagery data, national environmental data. The data from case study countries will be useful in preparing country-specific technical reports, policy briefs and other important messages.

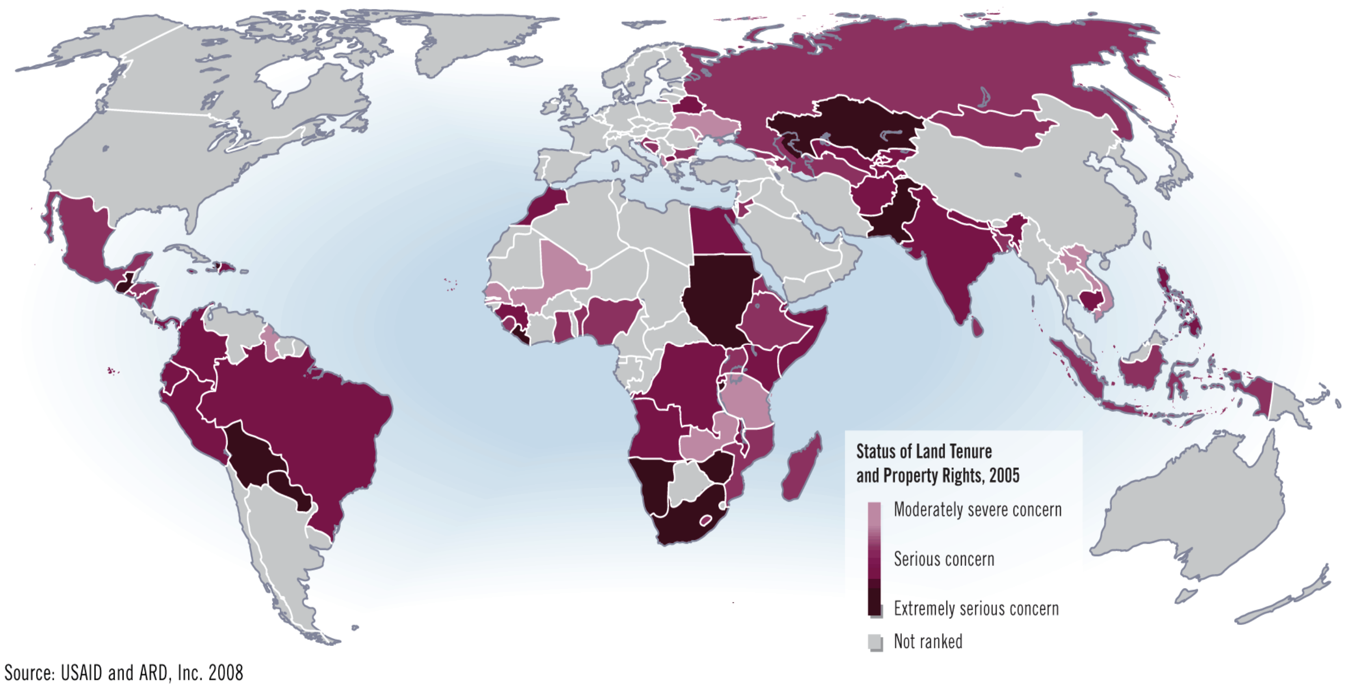

Figure 5. Status of land tenure and poverty rights, 2005

Table 6. Available household level data in the case study countries

	Poverty		Other drivers of LD	
	DHS – baseline	DHS - endline	Baseline	Endline
Argentina	None			
Ethiopia	2000	2005, 2011		
Kenya	1989 1993 1998	2003, 2008-09 2010	KIHS 2005	Tegemeo Panel data: 2000-2004, 2011
India	1992-93 1998-99	2005-06		
Niger	1992, 1998	2006		
Nigeria	1990, 1999	2003 2008 2010	i. Agric. surveys, 1983-1990 ii. IFPRI/Fadama panel survey, 2007	i. Agric. surveys 2005-2010 ii. IFPRI Fadama panel survey 2011[3]
Senegal	1986 1992-93 1999,	2005 2010-11		
Tanzania	1991-92 1994 1995,	2011-2012 2010		
Uzbekistan	1996	2002		
Zambia	1992 1996	2007 2005		

[3] See Nkonya et al (2012).

Table 7. Key variables and datasets required for the analysis

Categories	Variables	Scale (spatial/non-spatial)
Biophysical		
Climate	Mean, maximum and minimum temperatures, precipitation, solar radiation (crop modeling needs may require more)	Global (GIS) National from individual weather stations (daily and monthly)
Soils	Soil type and properties, existing soil degradation states, and soil quality/constraint	National and Global (GIS)
Biomass productivity	Human-induced long-term NDVI trend	Global (GIS)
Agro-ecological	Agro-ecological zones, farming systems, length of growing period, existing land cover and land use maps, topography	National and Global GIS
Experimental data for crop modeling	As per software needs, numerous	Plot-level
Economic		
Socio-economic characteristics	Income per capita, population density, poverty rates, infant mortality rates, etc Household demographic characteristics, income (farm and non-farm) and detailed expenses, asset ownership, physical and social capital, education levels, etc	Sub-national, national and household level
Agricultural production	Crop areas and yields, input use: seeds, fertilizers, chemicals, manure, water, labor, farm machinery, fuel, others Farm characteristics, livestock ownership, output marketing, previous land use changes	Household, district and national
Prices	Output and input prices, land values when available	Sub-national and national (time series) Purchased input and marketed output prices at household level
Institutional		
Institutional	Market access, access to extension and information, access to credit, road density, night time lighting intensity series, land tenure, Government effectiveness, household risk attitudes from field experiments, membership in associations	National and household, as appropriate
SLM practices		
SLM practices	Knowledge and use of SLM practices, sources of knowledge, perceived constraints on SLM adoption	Household
SLM policies	National policies having impact on land degradation and SLM: subsidies and taxes, land use planning and production quotas, export and import tariffs, barriers and quotas, etc	National
Others		
Indirect use, non-use, and off-site values	Obtained from literature, whenever possible, own data collection and estimation	Sub-national, national and global

Conclusions and Reflections of ELD study

This study is being conducted at a stage when there is an elevated interest in land investment and at a time when global efforts to achieve sustainable development have increased. The study is also being conducted at a time when spatial data availability and analytical methods have greatly improved. The proposed analytical method and data collection will contribute greatly in informing policy makers on the best action to address severe land degradation. The empirical results will also serve a key role in preparing key messages targeted to policy makers, donors and other stakeholders. Given the enormous amount of data and their significant differences, only an inter-disciplinary team, working closely with all local, national and international stakeholders, can afford to collect and analyze the ELD data. The ELD team reflects this crucial condition and will work closely to produce ELD results which would be crucial in land policy formulation at national and global level.

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Annex 1

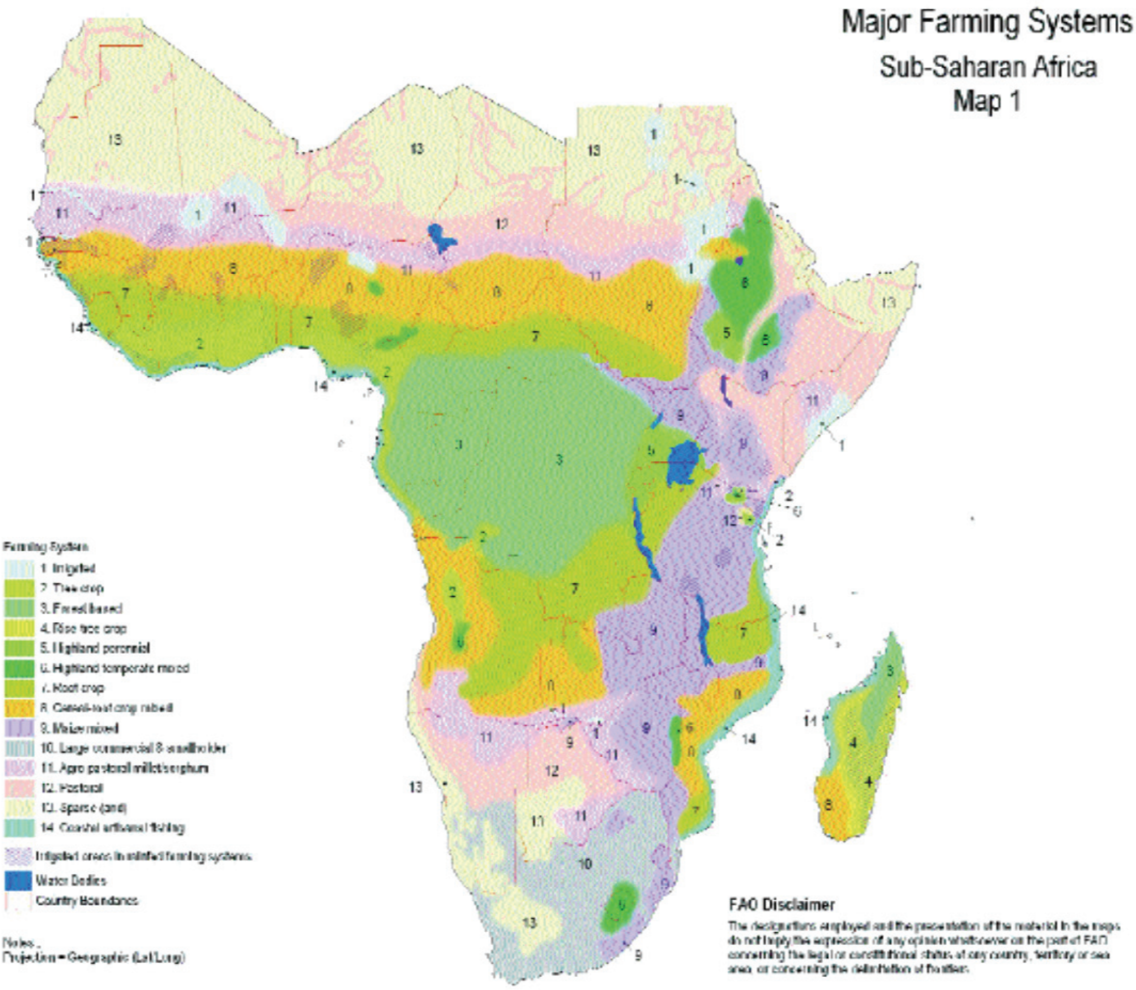
SSA farming systems

Farming Systems	Land Area % of region	Agric. Popn. (% of region)	Principal Livelihoods	Case study representing Farming system
Irrigated	1	2	Rice, cotton, vegetables, rainfed crops, cattle, poultry	Northern & central Nigeria
Tree Crop	3	6	Cocoa, coffee, oil palm, rubber, yams, maize, off-farm work	Central Kenya; Southern Nigeria All 4 countries
Forest Based	11	7	Cassava, maize, beans, cocoyams	Southern Nigeria; Central & Western Nigeria
Rice-Tree Crop	1	2	Rice, banana, coffee, maize, cassava, legumes, livestock, off-farm work	Central & Western Kenya; Northern Nigeria
Highland Perennial	1	8	Banana, plantain, enset, coffee, cassava, sweet potato, beans, cereals, livestock, poultry, off-farm work	Central Kenya
Highland Temperate - mixed	2	7	Wheat barley, tef, peas, lentils, broadbeans, rape, potatoes, sheep, goats, livestock, poultry, off-farm work	Central Kenya All four countries
Root Crop	11	11	Yams, cassava, legumes, off-farm work	Southern Nigeria
Cereal-Root Crop mixed	13	15	Maize, sorghum, millet, cassava, yams, legumes, cattle	Kenya, Northern Nigeria
Maize Mixed	10	15	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work	Western Kenya; northern & central Nigeria
Large Commercial & Smallholder	5	4	Maize, pulses, sunflower, cattle, sheep, goats, remittances	Central & Western Kenya; Other countries
Agro-Pastoral Millet/Sorghum	8	8	Sorghum, pearl millet, pulses. sesame, cattle, sheep, goats, poultry, off-farm work	Niger, Northern Nigeria; northwestern Senegal
Pastoral	14	7	Cattle, camels, sheep, goats, remittances	Niger, Northern Nigeria, northern Kenya
Sparse (Arid)	17	1	Irrigated maize, vegetables, date palms, cattle, off-farm work	Northern Nigeria;
Coastal Artisanal	2	3	Marine fish, coconuts, cashew,	Southern Nigeria

Fishing			banana, yams, fruit, goats, poultry, off-farm work	
Urban Based	little	3	Fruit, vegetables, dairy, cattle, goats, poultry, off-farm work	Urban areas, all countries

Source: Dixon et al (2001) - http://www.fao.org/docrep/003/Y1860E/y1860e04.htm

Sub-Saharan Africa Farming systems



South Asia farming systems

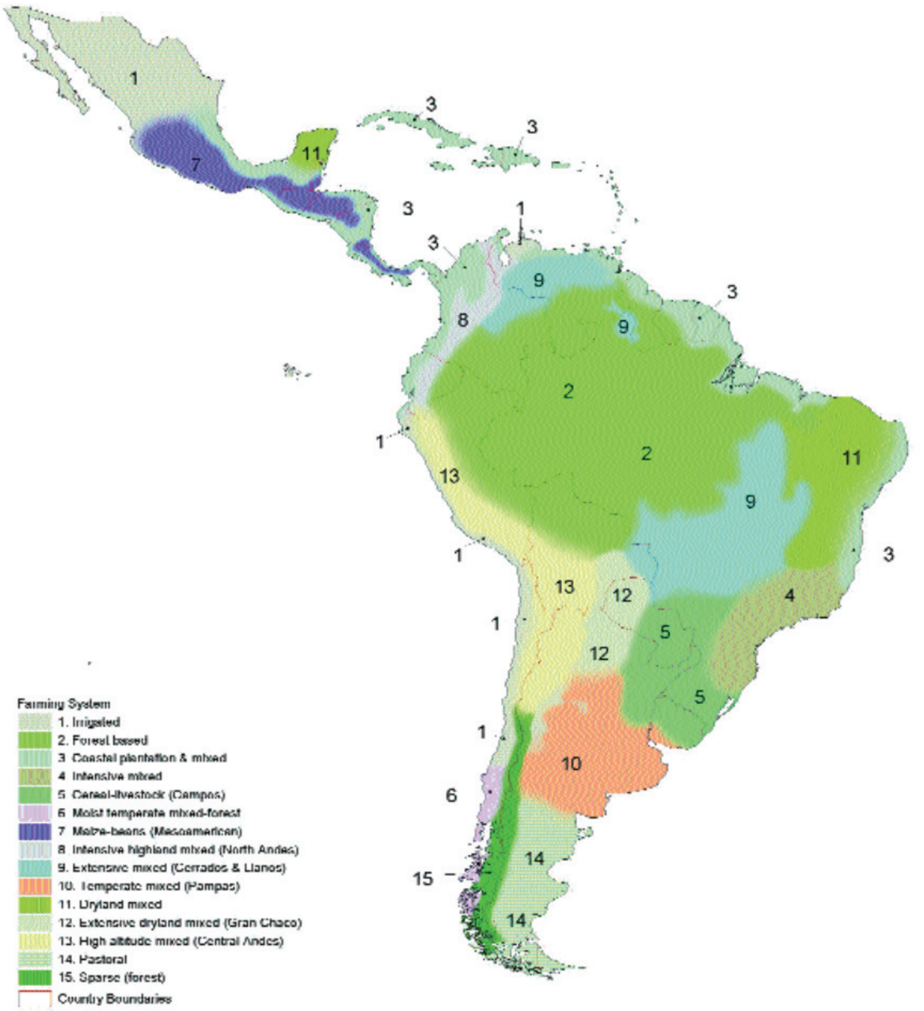
Farming Systems	Land Area (% of region)	Agric. Popn.(% of region)	Principal Livelihoods	Case study representing farming systems
Rice	7	17	Wetland rice (both seasons), vegetables, legumes, off-farm activities	Central & Southern India
Coastal Artisanal Fishing	1	2	Fishing, coconuts, rice, legumes, livestock	India coastal areas
Rice-Wheat	19	33	Irrigated Rice, wheat, vegetables, livestock including dairy, off-farm activities	Central & western states & West Bengal states
Highland Mixed	12	7	Cereals, livestock, horticulture, seasonal migration	Northern India
Rainfed Mixed	29	30	Cereals, legumes, fodder crops, livestock, off-farm activities	Central India
Dry Rainfed	4	4	Coarse cereals, irrigated cereals, legumes, off-farm activities	
Pastoral	11	3	Livestock, irrigated cropping, migration	Rajasthan India
Sparse (Arid)	11	1	Livestock where seasonal moisture permits	
Sparse (Mountain)	7	0.4	Summer grazing of livestock	
Tree Crop	Dispersed	1	Export or agro-industrialcrops, cereals, wage labour	
Urban Based	<1	1	Horticulture, dairying, poultry, other activities	

Source: http://www.fao.org/docrep/003/Y1860E/y1860e07.htm

Latin America & Carribean farming systems

Farming Systems	Land Area (% of region)	Agric. Pop (% of region)	Principal Livelihoods	Case country representing farming systems
Irrigated	10	9	Horticulture, fruit, cattle	Western Argentina
Forest Based	30	9	Subsistence/cattle ranching	North-eastern Argentina
Coastal Plantation and Mixed	9	17	Export crops/tree crops, fishing, tubers, tourism	South-eastern Argentina
Intensive Mixed	4	8	Coffee, horticulture, fruit, off-farm work	
Cereal-Livestock (Campos)	5	6	Rice & livestock	Northern Argentina
Moist Temperate Mixed-Forest	1	1	Dairy, beef, cereals, forestry, tourism	Northern Argentina
Maize-Beans Mesoamerican)	3	10	Maize, beans, coffee, horticulture, off-farm work	
Intensive Highlands Mixed (Northern Andes)	2	3	Vegetables, maize, coffee, cattle/pigs, cereals, potatoes, off-farm work	North-eastern Argentina
Extensive Mixed (Cerrados & Llanos)	11	9	Livestock, oilseeds, grains, some coffee	Eastern Argentina
Temperate Mixed (Pampas)	5	6	Livestock, wheat, soybean	Central Argentina
Dryland Mixed	6	9	Livestock, maize, cassava, wage labour, seasonal migration	Patagonia Argentina
Extensive Dryland Mixed (Gran Chaco)	3	2	Livestock, cotton, subsistence crops	
High Altitude Mixed (Central Andes)	6	7	Tubers, sheep, grains, llamas, vegetables, off-farm work	
Pastoral	3	1	Sheep, cattle	
Sparse (Forest)	1	<1	Sheep, cattle, forest extraction, tourism	
Urban Based	<1	3	Horticulture, dairy, poultry	

Latin America and Carribean Farming systems



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The designations employed and the presentation of the material in the maps do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers.

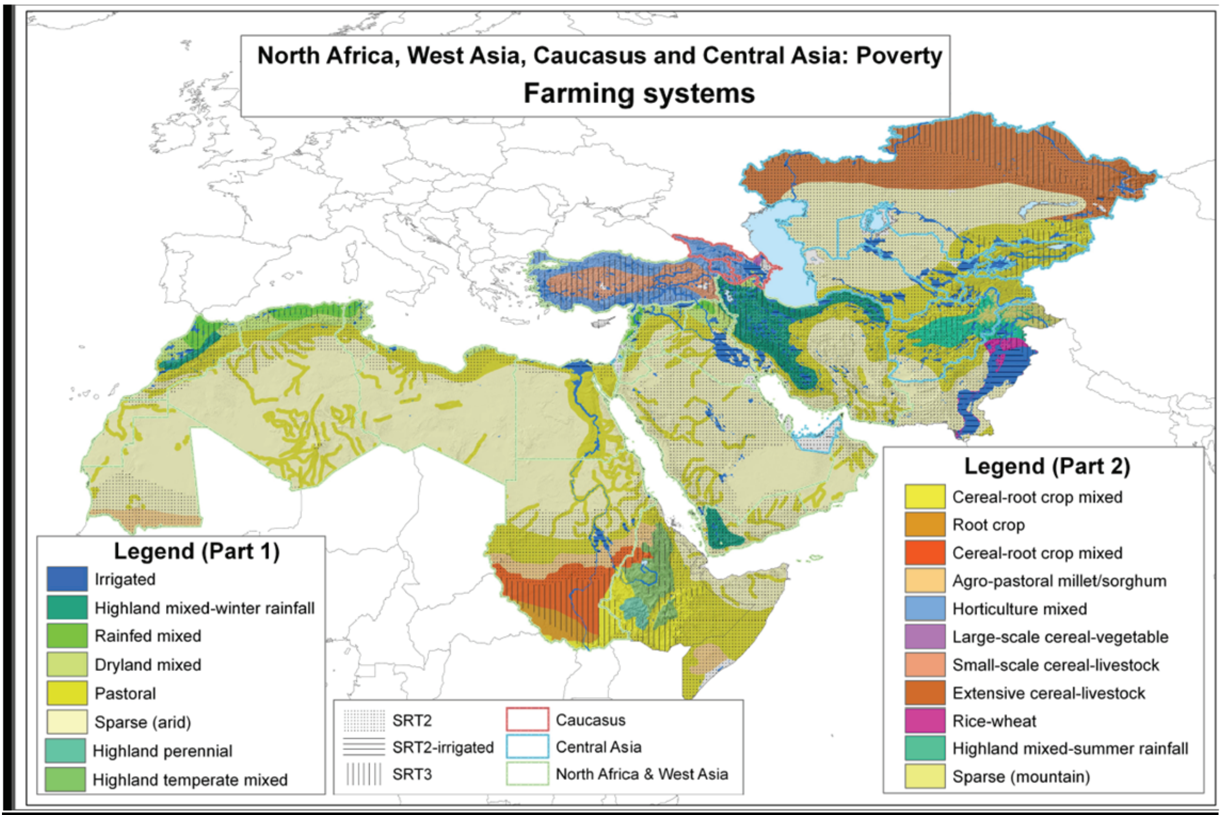
Note :
Projection – Geographic (Lat/Long)
Map Production Data Aquisition and Spatial Analysis Team,
UN FAO/World Bank Global Farming Systems Study

East Europe & Central Asia farming systems

Farming system	% of land area	% of population	Agricultural Household Livelihoods	Corresponding areas in Uzbekistan
Irrigated	1	4	Cotton, wheat, rice, off-farm, other cereals, fruit, vegetables	North-western, central and eastern
Mixed	4	18	Wheat, maize, oilseeds, barley, livestock	Central and Eastern
Forest based livestock	3	5	Fodder, hay, cereals, potatoes	minor
Horticultural mixed	3	11	Wheat, maize, oilseeds, fruit, intensive extensive vegetables, livestock, off-farm income	Eastern
Large-scale cereal vegetable	4	16	Wheat, barley, maize, Moderate - Vegetable sunflower, sugarbeet, extensive vegetables	minor
Small-scale cereal livestock	1	4	Wheat, barley, sheep, Livestock and goats	Central
Extensive cereal-livestock	18	15	Wheat, hay, fodder, Moderate - Cereal-Livestock cattle, sheep	minor
Pastoral	3	10	Sheep, cattle, cereals, fodder crops, potatoes	Southern and South-Eastern
Sparse (cold)	52	2	Rye, oats, potatoes, forestry	minor
Sparse (arid)	6	8	Barley, sheep	Central
Urban	<1	7	Vegetable, poultry	Mainly, north-western and eastern

Source: Dixon et al 2001

NENA and Central Asia farming systems



Source: de Pauw and Altassi (2011) based on Dixon et al. (2001)
http://crp11.icarda.cgiar.org/crp/public/files/maps/Farming_Systems_CWANA.pdf