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UNCCD 2nd Scientific Conference Extended Abstracts

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Oral Presentations

A Land-Potential Knowledge System (LandPKS) Based on Local and Scientific Knowledge of Land Productivity and Resilience

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ABSTRACT: Economic assessment of land use change in drylands depends on understanding potential productivity, degradation resistance and resilience, all of which vary widely and are often ignored. Rapidly increasing demand, together with new technologies, migration and global capital mobility are driving dramatic land use changes. Management practices that are productive and sustainable on one type of land may, when applied to adjacent lands, result in irreversible degradation due to differences in soil, topography and climate. Conversely, lessons learned on land separated by thousands of kilometers are often relevant, provided that similar conditions exist. New technologies, including cloud-computing, digital soil mapping, GPS-enabled camera phones, and mobile 'apps' now provide the opportunity to gather, integrate and share new knowledge and information about land potential, while global databases make existing knowledge more accessible and easier to match to relevant conditions. A new "Land-Potential Knowledge System" (LandPKS) will integrate existing natural resource databases with targeted field data collection of knowledge and information using new cell phone-based tools. An understanding of land potential can be used to determine where: (1) land is not meeting its productive potential (for all ecosystem services), (2) unrealistic expectations are driving unsustainable development investments, and (3) proposed intensification is likely to lead to irreversible degradation. Decision tools will support land use planning and targeted interventions by governments, development and conservation organizations and farmers. Knowledge of land potential can dramatically increase the return on investment by focusing resources on sustainable land uses and management strategies.

Keywords: Soil, Decision support system, Sustainable land management, Mobile phones, Mobile apps,

1. INTRODUCTION

Global demand for agricultural production of food, fiber and fuel is increasing rapidly in response to growth in both population and per-capita consumption. In addition to reducing consumption there are two options to address this burgeoning demand: increasing agricultural land area, and intensifying production on existing agricultural lands. A recent analysis suggests that even with intensification, 285 – 792 Mha of current grasslands, shrublands, savanna and forest will be converted to agricultural production and urban expansion (Lambin and Meyfroidt, 2011). Economic assessments of land use options are limited by a lack of understanding of how potential production, land degradation resistance and resilience vary at field to global scales. The estimate that in 1999 38% of soils under agriculture (not including permanent pasture and woodlands) were degraded is based on expert knowledge, backed by essentially anecdotal (at the global scale) on-site assessments and analyses (Scherr, 1999). Estimates of how these numbers may have changed over the past 13 years, how much of this land could be restored, at what cost, and to what level of production, are even less reliable due to a lack of information on potential production, natural resilience, and response to management inputs. In this paper, we argue that both sustainable intensification of currently degraded and undegraded agricultural lands, and sustainably maximizing the benefits of agricultural conversion of additional land, depend on understanding land potential.

1.1 What is land potential?

Land potential is defined here as the potential of the land to support the production of ecosystem services, its resistance to degradation and its resilience. The first component, potential production, commonly refers to agricultural production or, more broadly, net primary production. However, the concept can be expanded to include other ecosystem services including the provision of water quality and quantity and biodiversity conservation. Land potential also includes the potential of the land to sustain productivity following disturbance. This depends on a combination of degradation resistance and resilience, or its capacity to recover (Seybold et al. 1999). In the ecological literature, the term resilience is often used to refer to both degradation resistance and capacity to recover, including both the extent and rate of recovery.

1.2 Implications for GIS-based global assessments and land use planning

Uncertainty about land potential limits the value of global assessments because an assessment requires a reliable reference point. More importantly, decisions about how to target and optimize the impact of the limited resources available for sustainably increasing production and choosing which lands should be converted to agriculture are often made with little regard for the basic physical factors that ultimately determine both short- and long-term returns on these investments. Where this information is available, it is generally provided in the form of maps, which group often diverse soils into map units. Land use planners, private investors and international development organizations then either average the properties of the soils across the map unit, or represent the entire map unit with the properties of the dominant soil, which can cover far less than 50% of the map unit. In areas with broadly similar soils, such as landscapes with deep loess deposits and old lakebeds, this approach is appropriate because the scale of landscape heterogeneity is more similar to the scale represented by map units.

In much of the world, however, soil forming processes have resulted in fine scale mosaics of soils, each with unique potential productivity degradation resistance and resilience. For example, many alluvial plains are covered by a complex soil mosaic produced by deposition of different types of materials in old river and stream channels. Coarse sand can alternate with loams or even clay at a scale of tens of meters. These differences, which can change plant-available water holding capacity by a factor of two or more, are often obscured by a spatially homogenous surface layer deposited by wind or floodwaters after the channels moved to another part of the landscape. Similar differences can result from alluvial deposition of coarse sand across the margin of an old lakebed (Figure 1).

Soil texture differences largely determine plant-available water holding capacity; these differences are important because they determine how long plants can survive between large precipitation events. Surface texture differences also determine the potential infiltration capacity of the soil, which can impact ecosystem services related to not only production, but also water quality and quantity. Finally, texture, together with soil organic matter content and clay mineralogy, determines soil nutrient retention capacity. Other factors, such as soil mineralogy, slope, slope shape and aspect, also affect potential productivity as well as resilience.

A recent scoping study completed in Turkana Kenya (Losinyen, 2012), together with additional informal producer interviews in Laikipia and Samburu, Kenya, and in northern Namibia, all indicated that while there is a great deal of local knowledge about general patterns of land potential, this knowledge is often limited where long-term overgrazing has resulted in shifts to less productive or palatable vegetation, obscuring soil potential. These studies and interviews, together with the success of mobile apps such as mPesa, also indicate a high social capacity to adopt new technologies based on mobile phones.

2. NEW TECHNOLOGIES: AN OPPORTUNITY

New technologies, including cloud computing, digital soil mapping, GPS-enabled camera phones and mobile 'apps' now provide the opportunity to gather, integrate and share new knowledge and information about land potential, degradation resistance and

resilience, while global databases make existing knowledge more accessible and easier to match to relevant conditions (Herrick and Sarukhan, 2007). GPS-enabled camera phones or 'smartphones' allow individuals to capture and transmit geolocated photographs of soil, land use, and erosion features. The Global Soil Map consortium was established in response to the soaring demand for up-to-date and relevant soil information (Sanchez et al. 2009). The consortium consists of leading soil science institutions from around the world, committed to the task of producing digital soil maps that will predict important soil properties at a fine resolution using state-of-the-art and emerging technologies for soil mapping. This raster based soil information allows for completely new ways of acquiring, disseminating and using soil information. Apps can be used to record additional information about a site using drop-down menus, text-input, and picture-matching. Slope and color can also be determined with many phones, and the USDA (ARS-Jornada and NRCS-Lincoln), with collaborative support from ICRAF (Shepherd and Walsh, 2007), is currently developing an app that will increase the quality of color determinations using an integrated calibration system. Cloud computing allows completion of relatively sophisticated analyses requiring access to large databases, while innovative analysis approaches allow different types of data of with currently unspecified error rates to be integrated (Hubbard, 2010).

Together, these tools allow local knowledge to be crowd-sourced and for different sources of knowledge and information to be cross-referenced. They enable users to make well informed site-specific interpretations about land potential which can then be shared virtually instantaneously. They also allow individuals with similar types of land and similar land management to find each other and share knowledge and information directly. The LandPKS will go beyond previous efforts to integrate local and scientific information (Barrios et al. 2006; Herrick et al. 2010) by allowing the site-specific conclusions to be constantly updated based on input from other locations with similar soil and climate characteristics. In other words, the database and program will develop in an iterative process, with benefits increasing with use.

3. A LAND-POTENTIAL KNOWLEDGE SYSTEM

A new "Land-Potential Knowledge System" (LandPKS; Figure 2) currently under development will integrate existing natural resource databases with targeted field data collection of knowledge and information using new cell phone-based tools. Multiple sources of knowledge and information will be accessed based on site-specific characteristics (Herrick and Sarukhan, 2007). Users will measure soil depth (up to 1m), provide a simple description of surface and subsurface texture, land cover and use, and observations of runoff and soil erosion. A geo-tagged photograph of the excavated soil together with an internal calibration reference will be used to determine soil color, while an oblique photograph will be used to confirm the land cover and use descriptions. These photographs and documentation will also serve as benchmarks for monitoring. Users will have the opportunity to provide additional information through a tiered, iterative series of questions based on both their initial inputs and additional information, such as slope, aspect, and simulated soil erosion, which can be accessed using the GPS location.

Together with additional information on local crops and management system, this information will be used to provide a set of site-specific management options, with an indication of potential production degradation resistance and resilience with and without additional inputs. Potential production metrics need not be limited to agricultural or biomass production, but could also include metrics such as water quality, water quantity, soil carbon, erosion reduction, and biodiversity.
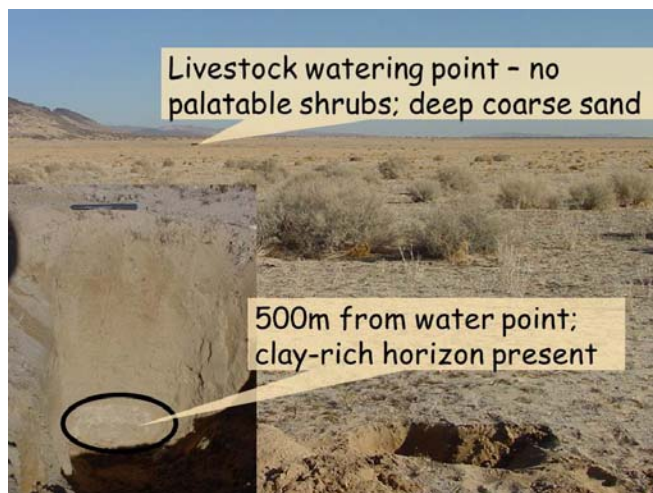

Fig. 1: Difference in land potential can easily be misinterpreted as differences in land condition (Mojave Desert, USA). For example, the lack of the palatable shrub Atriplex canescens (four-wing saltbush) near the water point in the background was initially interpreted to be the result of livestock grazing, as the same shrub was found growing 500m from the water point where the surface soil appeared to be virtually identical and where grazing was presumably less intense. Examination of the soil profile, however, revealed that the saltbush presence was correlated with a deep, fine-textured soil layer that holds more water than does deep sand.

With the exception of the local knowledge provided by user inputs, the system will be open-source, and will rely on existing knowledge and information databases, including those that have been and are being developed by the Global Soil Map program (globalsoilmap.net), African Soil Information System (africasoils.net), European Environment Agency (especially Eye on Earth-eyeonearth.org), and several CGIAR research centers (cgiar.org), as well as a number of sustainable land management knowledge systems including, but by no means limited to, WOCAT (wocat.net). LandPKS is being designed to be easily linked with related systems currently available and under development, including those providing market information and crop-specific fertilizer and pest-control recommendations.

The LandPKS will be developed in phases. The first phase will rely on simple decision support protocols based on basic user soil/site descriptions and existing land evaluation systems, including the Land Capability Classification system (LCC; Klingebiel and Montgomery, 1961), and the FAO's more comprehensive Agroecological Zoning system (AEZ; FAO, 2007). Phase II will begin to integrate user-provided knowledge and information about land response to different management systems into analyses and interpretations for land with similar biophysical potential. It is anticipated that socioeconomic factors will be integrated in Phase III.
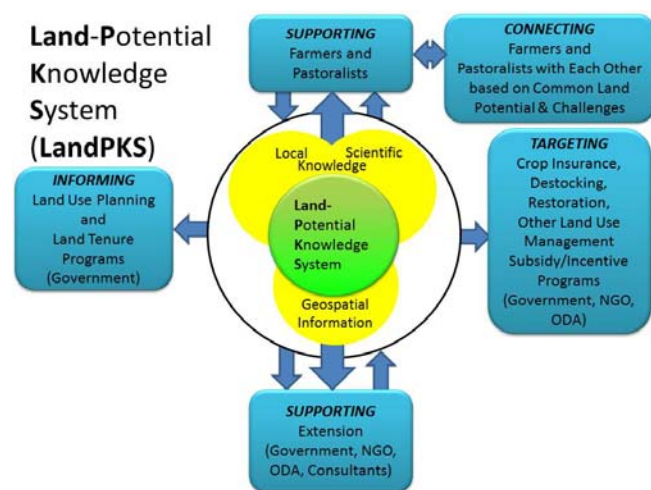

Fig. 2: Land-Potential Knowledge System (LandPKS; www.landpotential.org adapted from Herrick et al. 2013).

4. POLICY ORIENTED RECOMMENDATIONS

Decision tools and digital soil survey information will support land use planning and targeted interventions by governments, development and conservation organizations and farmers. Knowledge of land potential can dramatically increase the return on investment by focusing resources on sustainable land uses and management strategies.

5. CONCLUSIONS

An understanding of land potential can be used to determine where: (1) land is not meeting its productive potential (for all ecosystem services), (2) unrealistic expectations are driving unsustainable development investments, and (3) proposed intensification is likely to lead to irreversible degradation. The Land Potential Knowledge System (LandPKS) currently under development will allow farmers, development organizations, extension workers and national governments to share, access and apply the best available knowledge and information at field, regional, and national scales.

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