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International Resource Panel

UNLOCKING THE SUSTAINABLE POTENTIAL OF LAND RESOURCES

EVALUATION SYSTEMS, STRATEGIES AND TOOLS

Acknowledgments

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Working Group on Land and Soils

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Kara Shervanick, Holly Baker and Caitlin Holmes made significant contributions to the editing and preparation of this report. The following individuals participated in a workshop which resulted in the development some of the concepts outlined in the chapter on “Promoting innovation”: Susan Andrews, Matt Levi, Lee Norfleet, Dave Smith, Dennis Thompson, Norm Widman and Skye Wills.
The authors would like to thank the staff of the USDA-ARS Research Unit @ The Jornada for extensive logistical support. David Dent, David Rossiter and Keith Shepherd all provided helpful suggestions at several points in the revision process, and international participants in the UNU Land Restoration Training Course in Iceland provided feedback on presentation of some of the key concepts. We gratefully acknowledge USAID’s support for synergistic activities.
The report went through a peer review process coordinated by Yonglong Lu with the support of the IRP Secretariat. The authors thank the anonymous peer reviewers for their helpful suggestions.
Special thanks go to Janez Potočnik and Ashok Khosla as Co-Chairs of the IRP during the preparation of this report for their dedication and commitment, as well as to all members of the IRP and its Steering Committee for their constructive comments.
The Secretariat of the IRP coordinated the preparation of this report with the technical support of María José Baptista.

The main responsibility for errors remains with the authors.

Printed by: UNESCO
Design/layout: Marie Moncet, SOURIBLE
Cover photos@: 1. Ozphotoguy, Shutterstock.com; 2. Yury Birukov, Shutterstock.com; 3. Jimmy Tran, Shutterstock.com; 4. Hung Chung Chih, Shutterstock.com; 5. sunsinger, Shutterstock.com; 6. Don Mammoser, Shutterstock.com.

The full report should be referenced as follows
UNEP (2016) Unlocking the Sustainable Potential of Land Resources: Evaluation Systems, Strategies and Tools. A Report of the Working Group on Land and Soils of the International Resource Panel. Herrick, J.E., O. Arnalds, B. Bestelmeyer, S. Bringezu, G. Han, M.V. Johnson, D. Kimiti, Yihe Lu, L. Montanarella, W. Pengue, G. Toth, J. Tukahirwa, M. Velayutham, L. Zhang.

Job Number: DTI/2002/PA

ISBN: 978-92-807-3578-9

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Summary for Policymakers

UNLOCKING THE SUSTAINABLE POTENTIAL OF LAND RESOURCES

EVALUATION SYSTEMS, STRATEGIES AND TOOLS

Produced by the International Resource Panel.

This document highlights key findings from the report, and should be read in conjunction with the full report. References to research and reviews on which this report is based are listed in the full report.

The full report can be downloaded at http://www.unep.org/resourcepanel.
If you are reading a printed version, a CD-Rom can also be found in the back cover.

Additional copies can be ordered via email: resourcepanel@unep.org.

Preface

Dr. Janez Potočnik Alicia Bárcena

Co-Chairs, International Resource Panel

The International Resource Panel's first report on Land and Soil predicted that during the 45 years starting in 2005 there will be a net expansion of cropland of between 120 and 500 Mha. Compensating for land degradation and replacement of cropland with urban, industrial (including energy) and transportation infrastructure will result in a gross expansion of cropland of between 320 and 850 Mha under 'business as usual' conditions. This projected new cropland area is equal to over 50% of the current cropland area.

In addition to changing diets and reducing food waste and the demand for non-food uses of biomass, the Panel identified better matching of land use with land potential as a key factor in reducing the amount of land required to meet human needs. An improved understanding of land potential, in addition to more cost-effective and holistic tools for generating and sharing this understanding, is necessary to guide land use and management and, where necessary, to halt unsustainable land uses. More effectively matching land use with land potential is one of the few strategies available to decouple human development and economic growth from land degradation.

The first report on Land & Soil, "Assessing Global Land Use: Balancing Consumption with Sustainable Supply" concluded that two complementary strategies must be pursued: (1) apply sustainable land management strategies to all land, and (2) control the demand for the number of (cropland) hectares. The report identified several options for minimizing cropland expansion, including improved land use planning and land management "in order to minimize expansion of built-up land on fertile soils, and to invest in the restoration of degraded land". The current report focuses on land potential evaluation systems as a critical foundation for land use planning and management.

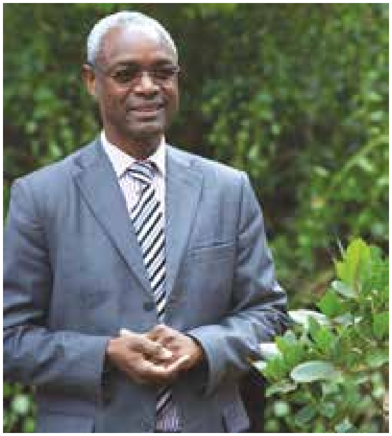
More specifically, land potential evaluation systems are needed to sustain and increase the provision of ecosystem services in the context of climate change, persistent land degradation and increasing global population and per-capita consumption levels by (a) guiding land tenure and land redistribution, and (b) promoting innovation to sustainably increase productivity and resource efficiency, including through sustainable intensification. Moreover, they can increase knowledge of locally utilized food varieties already adapted to specific land environments.

The application of land evaluation to land use planning and management is limited by four factors. The first is a lack of understanding of how to select and apply appropriate, currently available tools. The second is that existing land potential evaluation tools fail to account for resilience. The third is that they emphasize limits to production based on current technologies while ignoring and, in some cases, even constraining the development of innovative management systems that could increase land potential through an increase in resource productivity. Finally, and most importantly, socioeconomic and cultural constraints to land use and management must be addressed after or at the same time as the biophysical land evaluation. These constraints include, but are not limited to, land tenure, transportation and storage infrastructure, markets, and dietary preferences.

Together with the new IRP report "Food Systems and Natural Resources", this report supports the implementation of the UN Secretary-General's 'Zero Hunger Challenge' by addressing the first three factors. More specifically, this report provides background information, tools, and policy options necessary to implement the concept of "land degradation neutrality" included in the Rio+20 outcome document "The Future We Want" and in the agreed 2030 Agenda for Sustainable Development.

We thank Jeffrey Herrick and the rest of the working group for putting together this innovative assessment. We are confident that the principles set out in this report paired with the technology developed therewith will contribute to the development of the next generation of land potential evaluation systems, one which allows the inherent long-term land potential to be sustainably realized.

Foreword



Land resources are one of nature's most precious gifts. They feed us and help our societies and economies to thrive. Some 2.5 billion agricultural smallholders worldwide manage around 500 million small farms, providing more than 80 per cent of food consumed in Asia and Sub-Saharan Africa.

These resources are being degraded at an alarming pace. An estimated 33 per cent of soil is moderately to highly-degraded due to erosion, nutrient depletion, acidification, salinization, compaction and chemical pollution. Each year we lose 24 billion tonnes of fertile soil and 15 billion trees, costing the economy around $40 billion.

We are rapidly expanding global cropland at the expense of our savannahs, grasslands and forests, and, as the world's population increases, the demand for food, fibre and fuel will only increase the pressure on our land resource base. As previously noted by the International Resource Panel (IRP), if current conditions continue, between 320 and 849 million hectares of natural land may be converted to cropland by 2050. This unsustainable expansion of cropland coupled with the effects of climate change would impede the achievement of the Sustainable Development Goals, in particular SDG 15, which calls for a land degradation-neutral world by 2030.

Policymakers are confronted with a fundamental challenge. How can we sustainably produce food, fuel and fibre to meet future demand without further depleting our finite land resources?

The IRP seeks answers to this critical question. In this scientific assessment, Unlocking the Sustainable Potential of Land Resources: Evaluation Systems, Strategies and Tools, the Panel proposes matching land use with its potential, and in some cases even exceeding this potential, as one of the options. Based on a comprehensive analysis of existing land potential knowledge systems like the USDA Land

Capability Classification system and the FAO Agroecological Zoning System, the IRP suggests a new framework to evaluate land potential. This framework looks at variability in the factors that control land potential, addresses degradation resistance and resilience (the second of which is not considered at all in current systems), and acknowledges that the natural potential of the land to support multiple ecosystem services can be exceeded. The latter can be achieved through increased inputs and the implementation of innovative systems and technologies that increase resource use efficiency.

Important reductions in degradation have been achieved in the past through targeted policy interventions. For example, in the United States, owners of private land classified as "highly erodible land" were required to apply conservation practices as a pre-requisite to qualifying for some government programs. This requirement contributed to a dramatic 40 per cent reduction in soil erosion on US croplands between 1982 and 2007. Other policy tools proposed by the Panel include crop insurance subsidies limited to lands where the insured production system is sustainable, and tax breaks in exchange for long-term or permanent land conservation.

I am grateful to the International Resource Panel, for producing, under the leadership of Co-Chairs Alicia Bárcena and Janez Potočnik, a new kind of scientific assessment, one that provides practical policy guidance and technological solutions for the application of this guidance. I congratulate and thank the authors for this important effort in the road towards a land degradation-neutral world.

Ibrahim Thiaw
UNEP Deputy Executive Director

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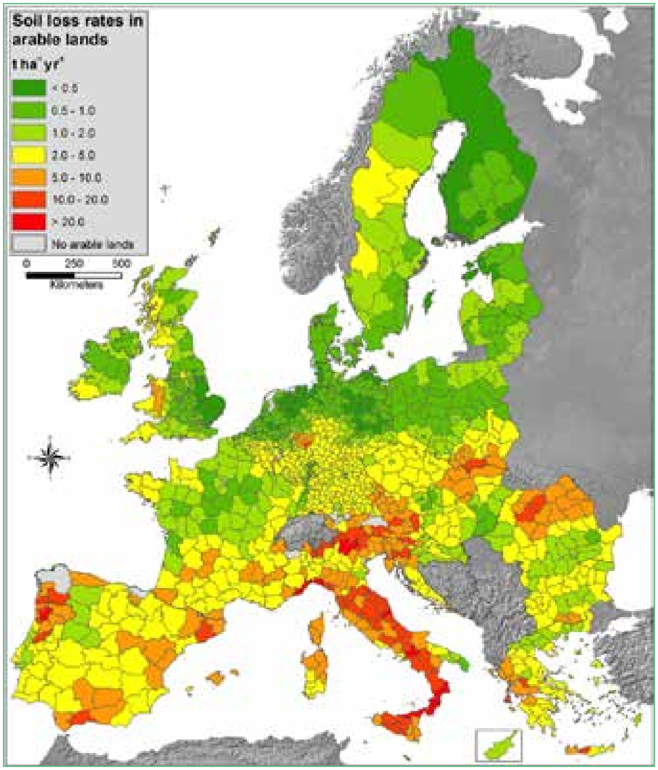
Summary

Land evaluation can be used by national policymakers, international development organizations, farmers, and conservationists to increase productivity, biodiversity conservation success, and to promote innovation. Land evaluation[1] helps make better decisions about how to use the land, and is therefore essential to achieving Land Degradation Neutrality (Sustainable Development Goal 15.3). An understanding of the long-term land potential is needed to (a) determine where production can be sustainably increased, and (b) identify land that could be restored.

Matching land use with its potential allows the inherent long-term potential to be sustainably realized. Sustainability depends on (1) potential degradation resistance, and (2) potential resilience, which is the capacity to recover

Figure 1. Modeled average annual soil loss in arable lands in EU countries



Source: (Panagos et al. 2015)

1. The focus of this report is on the inherent *long-term* (decades) potential of the land to *sustainably* generate ecosystem services, based on soils, topography, and climate. In general, land that can sustainably support higher levels of vegetation production, including crop, forage, and tree, has higher potential. *Short-term* land potential (1-5 years) depends on a combination of long-term potential, weather, and the current condition of the land (e.g. fertility, compaction, current vegetation cover).

from degradation. Land with similar potential should therefore respond similarly to management. Policymakers, development organizations, and land managers, including farmers and conservationists, can use land evaluation to:

- Increase productivity while adapting to climate change
  - Identify the most productive lands for a particular crop
  - Identify the most productive crop and management system for a particular piece of land
  - Determine what, and what level, of inputs are required to overcome limitations such as fertility, salinity, and drainage.
  - Target climate change adaptation investments to the soil - climate combinations with the greatest predicted return on investment
- Minimize social, economic, and environmental risks of land use change
  - Identify lands with high degradation risk
  - Identify management practices that can cost-effectively reduce degradation risk
  - Identify lands with high productivity and plan urban settlements out of these areas to minimize environmental impacts of next urbanization wave
- Increase restoration and biodiversity conservation success
  - Determine where restoration is most likely to be successful
  - Predict where endangered species are most likely to occur, for plants, soil biota and the animals that depend on them
  - Understand the restoration limitations for a particular piece of land
- Promote innovation and knowledge sharing
  - Allow innovators with different perspectives to quickly connect, find collaborators working on similar types of land and exchange best practices
  - Provide the ability to rapidly evaluate potential innovations under similar conditions
  - Increase the rate of upscaling of innovations by targeting areas where the innovations are most likely to be successful

Finally**, simple tools are available to complete and apply land evaluations at farm, watershed, regional and national scales.** For more information and links to these and other resources see “Selected sources” in the report; most are available through fao.org and/or landpotential.org.

Key messages

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1. Use land evaluation to sustainably increase agricultural productivity while adapting to climate change

Challenge

The Panel's first report on Land and Soil predicted that during the 45 years starting in 2005 there will be a net expansion of cropland of between 120 and 500 Mha. Compensating for land degradation and replacement of cropland with urban, industrial (including energy), and transportation infrastructure will result in a gross expansion of cropland of between 320 and 850 Mha under 'business as usual' conditions. This projected new cropland area is equal to over 50% of the current cropland area. Additionally, as pointed out by the IRP in the report on Food systems and Natural Resources, by 2050, an expected 40% of the world population will be living in severely water-stressed river basins and greenhouse gas emissions from agriculture may increase from 24% to 30%. The above-mentioned expansion of cropland coupled with the effects of climate change would impede the achievement of the Sustainable Development Goals (SDGs), in particular SDG 2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture); and 15 (protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

Policy options

Knowledge and understanding of land potential can be used in a number of ways to decouple increased agricultural production from additional land use change (including surface sealing associated with urbanization and infrastructure development) and land degradation. By evaluating land potential decision makers can:

- Identify existing agricultural lands where current production systems are unsustainable.
- Identify existing agricultural land where *true* "yield gaps" exist. Yield gaps based on comparisons within a region are often confused

by soil variability because the “reference” for the gap is often located on soil with relatively high potential production.

- Carefully match land use and management with land potential, ensuring the maximum sustainable benefit is achieved from each hectare of land, and target soil conservation to those lands with the greatest degradation risk.
- Target climate change adaptation investments to the soil - climate combinations with the greatest predicted return on investment

Example: design irrigation systems based on soil variability and crop requirements

Challenge: New irrigation schemes are being widely promoted to increase crop productivity per unit of land, and to a reduce risk of crop loss during dry years. Climate change is expected to increase water limitations during at least some years for many crop - soil combinations in much of the world.

Land evaluation response: The land potential evaluation information in the table can be used to plan land use and adapt to climate change in two ways. (1) Where irrigation is unavailable, crops can be matched to soil type to minimize the risk of yield losses during drought years. (2) Where new irrigation systems are implemented, they can be designed to preferentially deliver water to those soils with the greatest requirements.

Table 1. Average percent of years when various crops can be grown without irrigation for different soils in Norfolk, England

Soil Type	Spring barley	Sugar beets	Potatoes
	----------------	%	----------------
Peat	80	60	15
40 cm peat on compact till	55	35	15
Fine sandy loam	40	20	10
40 cm fine sandy loam over sand	30	10	5
Fine loamy over clay	20	15	5
Sand	5	5	0

Source: Calculated from data in Dent and Scammell, 1981.

Note: This illustrates that some soils have lower potential than others (e.g. sand), and that potential varies by crop, with spring barley being most tolerant to droughty soils. For example, spring barley can be grown on a fine sandy loam soil without irrigation 4 of 10 years (40%), but only 1 out of 20 years (5% on sandy soils).


Credit: Jimmy Tran, Shutterstock.com

2. Use land evaluation to avoid land degradation and environmental disasters

Challenge

Nearly every country can identify land where land degradation has caused virtually irreversible losses of agricultural productivity, long before the onset of climate change. In nearly every case, this was caused by a mis-match between land use and land potential. Catastrophic soil loss in the Mediterranean, dramatic declines in livestock production in the southwestern United States, and the complete loss of topsoil from hillsides throughout the Mediterranean all could have been avoided by managing the land within its limits. In virtually every case, land degradation has led to social dislocations and economic losses, in addition to off-site environmental consequences, including reduced air and water quality.

Opportunities

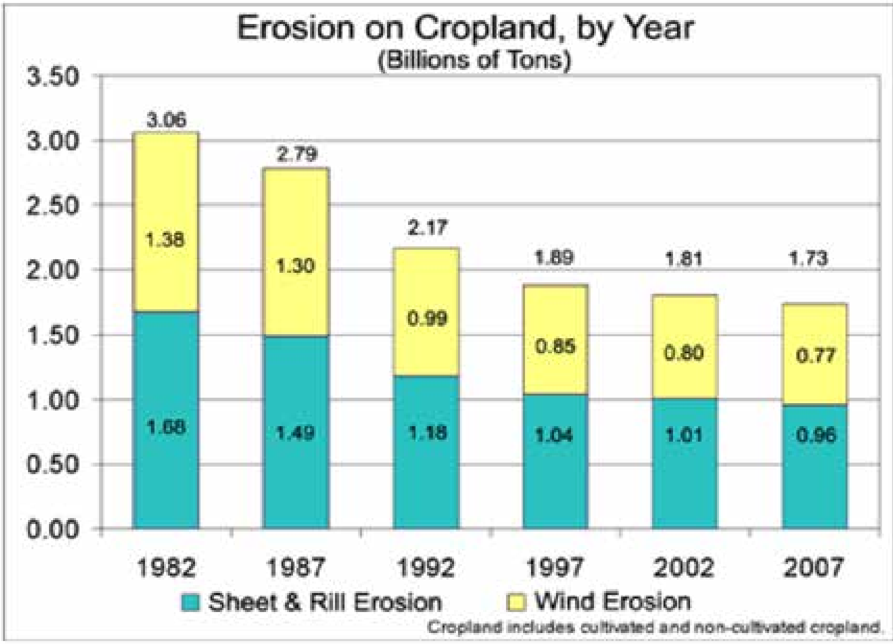
- Complete land evaluation *before* implementing policies that promote land use change.
- Consider land degradation risk under current and future climate, including inevitable "extreme events".
- Identify land use alternatives, and conservation practices to limit degradation.

Example: US 1930's "Dust Bowl"

Challenge: Billions of tons of soil were lost from the North American Great Plains during the "Dust Bowl" of the 1930's, causing massive poverty and migration (photos). It was caused by cultivation of lands that, while productive during wet years, could not sustain crop production during drought. Agricultural conversion of these semi-arid to dry sub-humid grasslands was actively promoted by a government programs.

Land evaluation response: The 8 class "Land Capability Classification System" was developed to guide agricultural land use. This system continues to be used, together with a definition of "Highly Erodible Lands", to support policy implementation at local, state, and federal levels. This has contributed to dramatic reductions in soil erosion on US cropland (graph).

Figure 2. Changes in soil erosion from US croplands between 1982 and 2007



Source: Based on USDA-NRCS National Resource Inventory data.

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3. Land evaluation to target resources for restoration and biodiversity conservation

Challenge

As highlighted in the IRP Food Systems and Natural Resources report, an estimated 33% of soils are moderately to highly degraded due to erosion, nutrient depletion, acidification, salinization, compaction and chemical pollution. Both land restoration and biodiversity conservation are key strategies in achieving a land-degradation-neutral world. These will require understanding what types of vegetation can be sustainably produced at what levels of production in each part of a landscape, region, or nation. This depends on soil.

Policy options

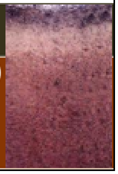
- Stratify land based on both its potential to support different habitat types (biodiversity conservation) and levels of production (restoration for both agricultural production and biodiversity conservation).
- Target investments and policy incentives to the most valuable parts of the landscape with the greatest degradation risk. Where resources are available for restoration, target investments and policy incentives to the most valuable parts of the landscape with the greatest restoration potential.

Example

Challenge: Large areas of the earth have been degraded, but not all can be restored. Restoration potential varies with both the inherent potential of the land (which depends on relatively static soil properties, topography, and climate), and its current condition (as reflected in vegetation cover and production, and relatively dynamic soil properties, such as soil organic matter and structure). In some cases, even the inherent potential has been lost due to soil loss. Soil loss reduces soil depth, but it can also result in changes in soil surface texture. Where increased clay is exposed at the soil surface, water infiltration can decline by 98% or more, making it virtually impossible to restore the land to its original condition.

Land evaluation response: Knowledge and information from other areas, including other parts of the world, can often be used to better predict the conditions under which various restoration approaches will and will not be successful. Including accurate descriptions of the soil, topography, climate, and weather can help others decide whether or not a successful example is relevant.

"Luverne sandy loam" soil in Alabama USA	Water Infiltration (mm/hr)
Surface (grey sandy loam 0-15cm)	35
Subsurface (red clay <15cm)	0.8 (-98%)



A combination of differences in soil, climate and management can all help explain the very different responses of a gully in Ethiopia (a) and (b) which resulted in a dramatic response after just 1 year, and a drier region of Kenya (c) which had not recovered after more than three years of restoration treatments. Source: G. Zeleke (a, b) and J. Herrick (c).


Credit: iladm, Shutterstock.com

4. Land evaluation to promote innovation and knowledge sharing

The most common way that an understanding of land potential can be used to sustainably increase production, without expanding onto non-agricultural lands, is better matching of land use with land potential. But what if an understanding of land potential could be used to make the production of ecosystem services increase *beyond* the current potential?

Increasing innovation rates

One of the simplest ways to accelerate innovation is to create knowledge sharing systems that allow innovators to easily and rapidly share their successes and failures. Rather than wasting time unknowingly replicating an existing system, innovators with access to knowledge can build on previous successes and avoid the failures. This accelerated communication is now occurring thanks to the Internet: news articles, blog posts, and videos quickly go viral.

The problem is that this information is rarely contextualized by the conditions of where the innovation did or did not work. For example, conservation tillage systems can be used to sustainably produce annual crops on low slopes, but are ineffective on steep slopes unless they are combined with other types of soil conservation measures. Even the steepness of the slope where they are sustainable depends on erodibility and infiltration capacity of the soil. This emphasizes the importance of promoting understanding of land potential in capacity building and awareness raising programs (see Policy Opportunities in main report).

Increasing adoption rates

Providing information about the factors that define land potential (soil, climate, and topography) for the locations where the innovative technologies and systems are tested is one of the simplest ways to accelerate the rate of innovation while reducing the costs. It is also one of the best ways to increase adoption of effective new systems. Innovators frequently complain that farmers are conservative. Research has shown that farmers are more likely to adopt systems they can easily test at relatively low cost and risk. Communicating with other farmers who have already tested the system under similar conditions can help speed adoption. The development of global crowdsourcing systems, which includes the ability to document or access existing soil, climate, and topography information for a given field location, now allows the results of early adopters' tests of an innovation to be shared.

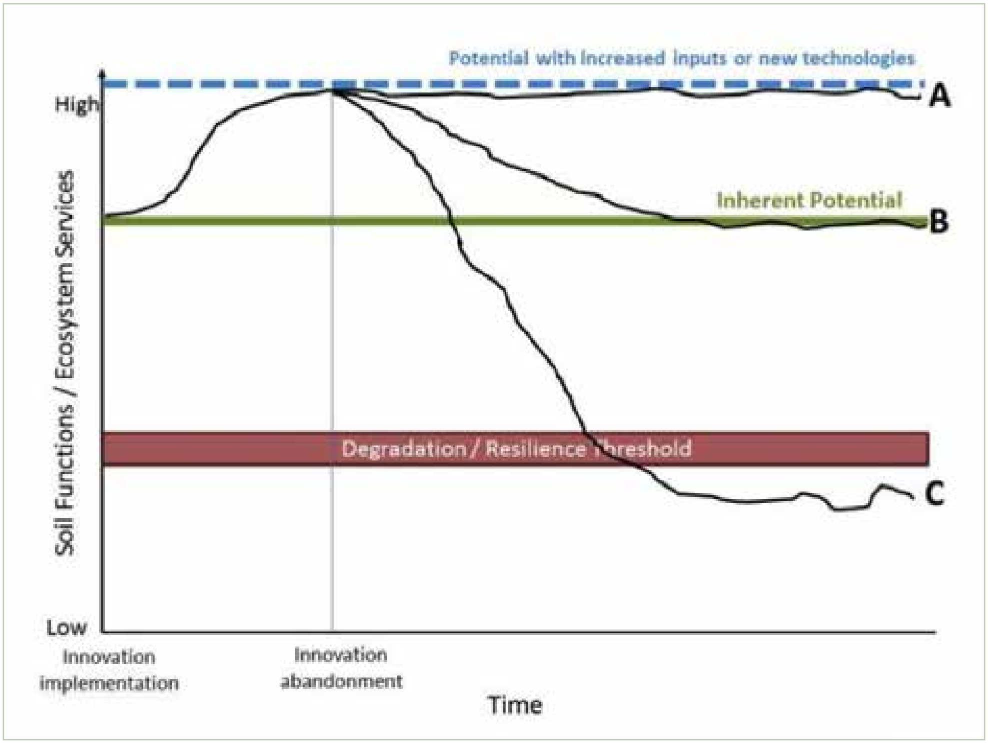
Raising the bar

Traditional land potential evaluation systems explicitly set an upper limit to what is possible. This potential can be exceeded by changing the relatively static properties that define the inherent potential. It can be temporarily modified with water and fertilizer inputs, or drainage systems.

Perhaps most exciting from a sustainability perspective, is that land potential can be increased through the implementation of innovative practices that effectively change the way that plants use existing water and nutrient resources. In other words, increasing resource use efficiency. The report proposes a framework that (1) addresses variability in the factors that control land potential, (2) addresses both degradation resistance and resilience by integrating thresholds, and (3) acknowledges that the natural potential of the land to support multiple ecosystem services can, in fact, be exceeded.

Exceeding the current potential can be achieved through permanently or temporarily modifying the inherent potential, through increased inputs, and through the implementation of innovative systems and technologies that increase resource use efficiency. Figure 3 shows both the promise and potential risk of exceeding land potential.

Figure 3. Possible outcomes following implementation and abandonment of an innovation or inputs that had increased the provision of one or more ecosystem services




Credit: Hung Chung Chin, Shutterstock.com

5. Simple tools to support land evaluation at farm, watershed, regional, and national scales

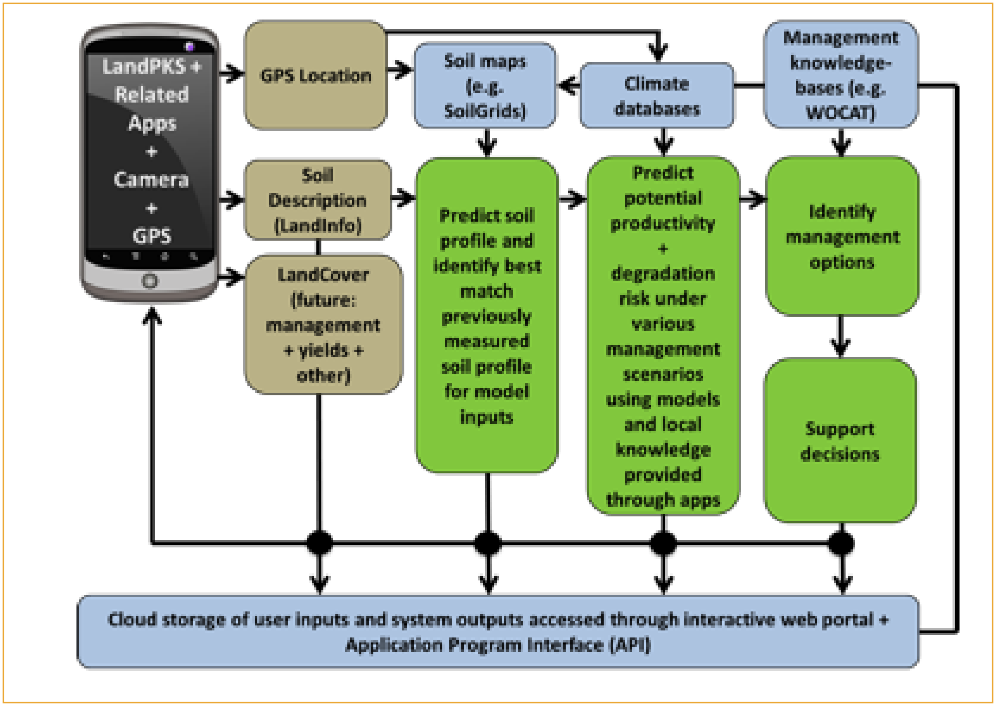
The two most widely applied land evaluation systems in the world are the USDA Land Capability Classification system and the FAO Agroecological Zoning System. The LCC system focuses on limitations to sustainable production. The AEZ provides more detailed predictions about which crops can be grown in what regions, but does not explicitly consider sustainability. A significant advantage of the AEZ is that predicted potential is provided for virtually the entire globe. These predictions must, however, be carefully interpreted because they are based on *predicted* soils for each location.

Figure 4. The Global Agroecological Zoning (GAEZ) portal

Source: Global Agroecological Zoning (GAEZ) website ("Agro-climatic yield" in the "Suitability and potential yield section of http://gaez.fao.org/Main.html#)

New tools are increasingly available that complement previously completed evaluations based on the LCC and AEZ by providing location-specific information. The Land-Potential Knowledge System (LandPKS) is one example being developed to provide real-time estimates of site-specific potential productivity, degradation resistance, and resilience via mobile technology. It integrates user inputs (soil and topography) with cloud-based geospatial layers and analytics to generate land potential estimates for specific locations. Future versions will integrate local and scientific knowledge to provide more detailed management options, including links to sustainable land management knowledge bases (such as WOCAT) and portals (such as the Scientific Knowledge Brokering Portal of the United Nations Convention to Combat Desertification).

Figure 5. The Land-Potential Knowledge System



Source: Adapted from Herrick et al., 2016.

Figure 5 shows how the Land-Potential Knowledge System (LandPKS – landpotential.org) is combining user input from mobile apps with cloud-based knowledge and information. This will provide site-specific knowledge and information that is relevant to the user's needs.

Four principles to improve existing land potential evaluation systems and develop the next generation

1. Assess disturbance, degradation and recovery.

Disturbance broadly includes anything that causes a change to the state of a system, including management. *Degradation* occurs when the disturbance causes a negative change in the capacity of the system to provide ecosystem services. While it is impossible to predict land response to disturbance with certainty, an understanding of soil and landscape processes can be used to improve predictions of land potential.

2. Include resilience in land potential evaluations.

Resilience is the capacity to recover from degradation, which can be quantified either in terms of the rate or extent of recovery within a specified time period at one or more spatial scales. While the degradation resistance (or capacity to maintain function through a disturbance) has been integrated into some widely applied land potential evaluation systems, like the USDA Land Capability Classification (LCC) system, resilience (the ability of the land to recover or the potential rate of recovery) is a critical missing element in all of these systems. A new generation of land potential evaluations could predict resilience to the dominant forms of land degradation (erosion, salinization, compaction in many areas) through the application of a relatively small number of indicators including precipitation, soil depth and texture by depth, and soil water holding capacity.

3. Integrate understanding of spatial scale into land potential evaluation systems.

When considering land classifications and making management decisions, it is important to ask the following questions: 1) What is the role of a land unit vs. the aggregation of units for landscape-level outcomes? 2) How can spatial interactions from the surrounding landscape affect my management objectives for a particular land unit? 3) How does the mapped information I have represent, or misrepresent, the spatial features of primary interest?

4. Evaluate land potential for ecosystem services.

Ecosystem services are benefits obtained from ecosystems that are essential for human existence. They are grouped in four categories: provisioning (e.g. food, fiber), regulatory (e.g. flood control, climate change; cultural (e.g. culture, religion); and supporting services (e.g. primary production, soil formation).

Nearly all existing major land potential evaluation systems (LCC, FAO's AEZ) prioritize food production over other ecosystem services. For instance, both the AEZ and LCC systems classify wetlands as temporarily or permanently not suitable for crop production while ignoring the value of wetlands in providing other ecosystem services. A three-step approach is proposed to facilitate the consideration of multiple ecosystem services in next generation land potential evaluation systems:

Step 1: determine **potential net primary productivity for the native ecosystem** associated with a soil and climate combination.

Step 2: determine, to the extent possible, the **maximum level of each ecosystem service** that can be supported on a per-hectare basis without reducing the future potential of the land to support other ecosystem services. This analysis must also identify tradeoffs and synergies when managing for multiple ecosystem services within the land's potential.

Step 3: Determine the **optimum level of each service** that can be supported for the set of ecosystem services of interest, taking into account tradeoffs and synergies, within the land's potential.


Credit: Don Mammoser, Shutterstock.com

The International Resource Panel showed in its first report on Land and Soil that without significant productivity increases, or decreases in the global per capita consumption of food and non-food biomass, the world's growing population will necessarily lead to an expansion of global cropland. The gross expansion of cropland under business as usual conditions will be 21 - 55% from 2005 to 2050. Matching land use with land potential is, therefore, a key factor in reducing the pressure on our land resources.

An improved understanding of land potential, in addition to more cost-effective and holistic tools for generating and sharing this understanding, is necessary to guide land use and management and, where necessary, to halt unsustainable land uses. More specifically, land potential evaluation systems are needed to sustain and increase the provision of ecosystem services in the context of climate change, persistent land degradation and increasing global population and per-capita consumption levels by (a) guiding land tenure and land redistribution, and (b) promoting innovation to sustainably increase productivity and resource efficiency, including through sustainable intensification. Matching more effectively land use with the land's potential is one of the few strategies available to decouple human development and economic growth from land degradation.

This new IRP report provides background information, tools, and policy options necessary to implement the concept of "land degradation neutrality" included in target 15.3 of the United Nations Sustainable Development Goals.

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UNEP

Job Number: DTI/2002/PA

ISBN: 978-92-807-3578-9