LANDPKS: A NEW MOBILE TOOL FOR SUSTAINABLE LAND-USE PLANNING AND MANAGEMENT

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Abstract

One of the major causes of poverty is poor land use planning and management. To address this issue, new technologies are needed that inform more sustainable land use planning and management. The Land-Potential Knowledge System (LandPKS; landpotential.org) provides a new approach to collecting spatial data with mobile phones in order to strengthen and enhance sustainable land use planning, and support sustainable land management. In Tanzania, the LandPKS team has been working with the National Land Use Planning Commission and USAID's Land Tenure Assistance (LTA) Project. On the biophysical side of land use planning process, Tanzania uses the Land Capability Classification system, which includes 8 classes. Categorizing the land into these classes helps planners to determine which livelihood activities are sustainable in which areas. LandPKS could play a key role in helping land use planners classify land into these eight classes; thus contributing to effective and sustainable land use planning and management.

Key Words:

LandPKS; Land Capability Classification; Land Use Planning; Tanzania; Sustainability

1. Introduction

As acknowledged in the United Nations Sustainable Development Goals (SDGs) for 2030, poverty remains to be one of the most serious issues facing humanity (United Nations 2015). One of the major root causes of poverty is poor land use planning and unsustainable land use and management. When landscapes are not managed sustainably, it can lead to land degradation, loss of livelihoods, and a decrease in the overall resilience of the social-ecological system (Liu 2014). This leads to a continued cycle of land degradation and poverty. Poverty leads people to practice unsustainable land uses, and land degradation further degrades natural resources and contributes to poverty.

However, land use planning that is effective, affordable, and socially just can have significant positive impacts on both people and the environment. For example, land use planning can positively contribute to many of the SDGs (United Nations 2015) as illustrated in Figure 1. Land use planning efforts have the potential to increase agricultural productivity, food security, and incomes of smallholder farmers. Through securing equal access to land for both men and women, land use planning can contribute to gender equality globally. Land use planning efforts can protect critical ecosystem services, such as clean water, and promote awareness of sustainable development that matches the potential of the land. Further, land use planning that matches appropriate land-uses with suitable land can strengthen the resilience of people and the environment to climate-related hazards, as well as contribute to a land-degradation neutral

Figure 1. How effective, affordable, and socially just land use planning can positively contribute to the 2030 SDGs.

world. Lastly, effective land use planning can help promote wildlife and biodiversity conservation by creating space on the landscape for people, flora, and fauna.

Generally, land-use planning is the assessment of different land uses with the purpose of selecting the best land use options and ensuring that land gets dedicated to its most suitable use (Rudel and Meyfroidt 2014). A land use plan is meant to express a vision of the future and can be carried out at a variety of scales including at national, regional, state and municipal levels (Shafer 2015). In theory, a land use plan should involve an assessment of land and water resources, as well as economic and social conditions to select the best land use options suitable for the land (Lambin et al. 2014). When done successfully, land use planning can help address a variety of environmental and social issues, such as the SDGs outlined in Figure 1. For example, Chaturvedi et al. (2015) found that in India, land-use planning that integrates both community participation and scientific assessment of biophysical conditions can and does lead to a significant improvement in agricultural productivity and consequently economic development. This example also highlights the importance of integrating both the biophysical and the social/economic/political characteristics of an area into effective land use planning. Due to this, many countries, including Tanzania have developed a participatory land use planning process that aims to include community involvement in each step.

However, better land use planning is needed to thwart environmental degradation, ecosystem fragmentation, and unsustainable land uses (Shafer 2015). In reality, the implementation of the land use planning process, as well as the enforcement of plans, can be a cumbersome and challenging process (Kisambu et al. 2017). Assessing biophysical characteristics of the land is especially difficult given the need for more sophisticated spatial evaluation tools and techniques (Lambin et al. 2014). Proper equipment, tools, and trained professionals may be insufficient or completing lacking particularly in the developing world context. For example, in Tanzania, the Land Use Planning Act of 2007 requires that villages conduct land use planning through a formal survey, something few communities have either the capacity or financial resources to conduct (Kisambu et al. 2017).

To address this issue, tools are needed to aid in assessing the biophysical characteristics of the land during the land use planning process. Such tools should be innovative, simple to use, affordable, global, and focused on providing useful information which can help to inform more sustainable land use planning and management. The Land-Potential Knowledge System (LandPKS; landpotential.org) is a new, innovative technology that collects spatial data about soils and vegetation with mobile phones in order to strengthen and enhance sustainable land-use planning, and support sustainable land management. In this paper, we will discuss the LandPKS project, how it can benefit land use planning efforts, and then focus on Tanzania as a case study and proof of concept.

2. The Land Potential Knowledge System: LandPKS Mobile Application

2.1 Overview of LandPKS

The LandPKS project was created to help put valuable information about land, including climate, soils, and vegetation in the hands of land managers and land use planners across the world. It does this through the use of the LandPKS Mobile app, which is free to download and use for both Android and iPhone. Importantly, LandPKS is a way to both input and access data that is point-based and geo-referenced; important characteristics for the land use planning process. The point-based model used by LandPKS is incredibly powerful because in many parts of the world the soils vary significantly from place to place and these changes in soil types can have dramatic impacts for farmers and others aiming to use the land. For example, a soil with a high clay content has different abilities to hold water for use by crops and risk of erosion than a soil with a high sand content. This then impacts what types of crops are most suitable to any given soil type, and planting crops in soils suitable to the crop physiology can increase productivity and decrease land degradation risks and impacts.

LandPKS currently has two modules: LandCover and LandInfo (Herrick et al. 2013). LandCover helps users monitor vegetation change and delivers vegetation cover results directly to a user's mobile phone. LandInfo uses short, animated, and icon-based tutorials to help the user determine soil properties, such as soil texture by depth, which are important in characterizing overall land potential. These user inputs in both LandCover and LandInfo are geo-located and can be uploaded from the user's smartphone to the cloud when the phone next has data access. Texture by depth is used together with existing soil databases to identify the soil type and estimate soil properties at the user's specific location. LandPKS uses cloud computing to integrate, interpret, and access relevant knowledge and information, and then deliver simple outputs to the user in order to help them make more sustainable land management decisions based on the potential of their land.

LandInfo aims to help farmers determine the potential of their soil, and thus make better decisions about agrochemical use, seed types, and crop varieties that are suitable to the soil in the long-term. LandCover can be used to monitor vegetation change, bare ground, growth of invasive, undesirable, species, or beneficial plants and fodder species. These results are important particularly in vegetation restoration efforts, and can help identify areas on the landscape in need of protection and rehabilitation. All LandPKS user data is publicly available on the LandPKS portal (landpotential.org), allowing for sharing of information among users. In the future, LandPKS will develop modules focused on monitoring agricultural crop production, measuring vegetation biomass, and assessing and monitoring soil health.

2.2 LandPKS in Action in Tanzania

Before we delve into the benefits of the LandPKS App for land use planning, it is important to highlight the added value of this tool for characterizing the biophysical aspects of a landscape. One excellent example is from the village of Nyamihuu, located near Iringa, Tanzania (image below). With local farmers, the LandPKS team dug three LandInfo soil pits within a short distance from each other on a slightly sloping landscape: *Lower field*, *Upper Field*, and *Forest*. The differences in soil texture and available water holding capacity (AWC; the potential plant-available water stored in the soil profile) were quite drastic, with the *Lower Field* having almost double the AWC of the *Upper Field*. This has serious implications for farmers because the *Lower Field* will be generally more productive due to the greater ability to hold water in the soil for crops to utilize. Further, the *Forest* plot had by far the lowest AWC,

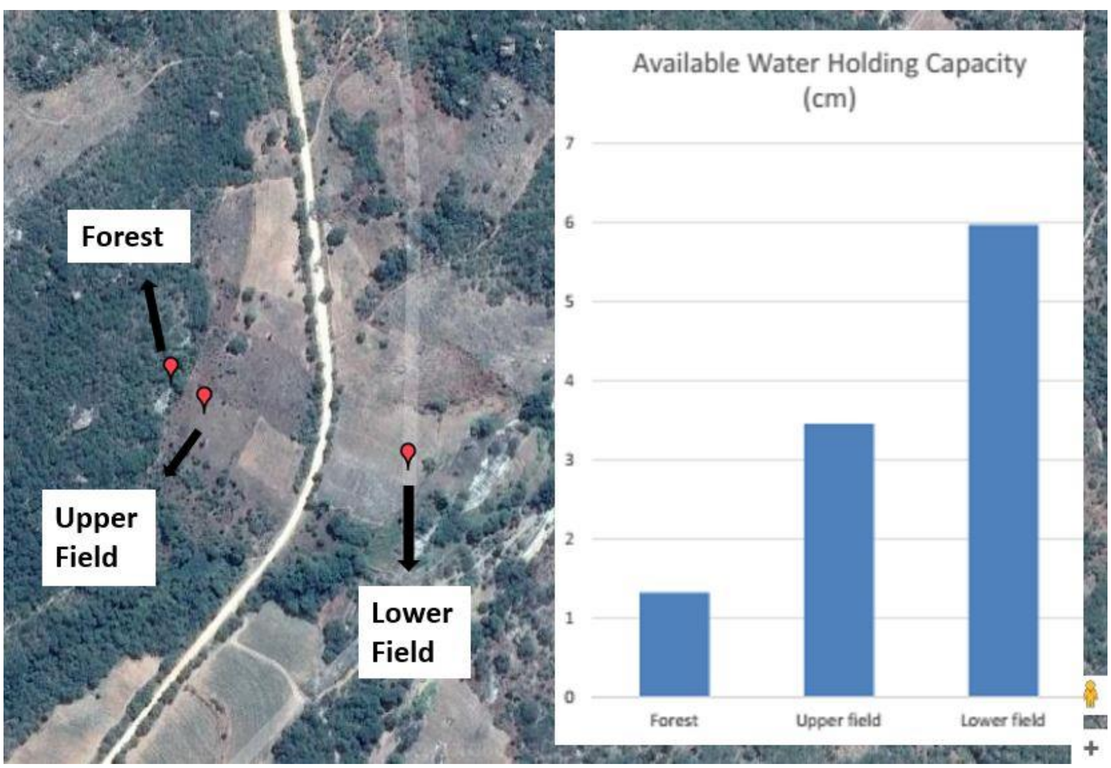

Figure 2. LandPKS plots dug in three sites in Nyamihuu, Tanzania (*Lower Field*, *Upper Field*, and *Forest*, and the LandPKS results for Available Water Holding Capacity for each location.

which is important because it suggests that clearing the forest for cultivation may not be worth the effort and environmental impact. The results from these three LandPKS LandInfo plots contain valuable information to land use planners in terms of which areas are suitable for which land use practices. They can help determine where the most suitable farmland is and where the landscape should perhaps be kept as forestland to provide valuable ecosystem services and forest products.

3. Land-Use Planning and LandPKS

3.1 Integrating LandPKS into Land Use Planning

LandPKS provides a new, innovative tool using spatial data to support effective land use planning and sustainable land management. However, in order to streamline the use of LandPKS in land use planning, the LandPKS team is developing a new module which takes the current user inputs, along with perhaps a few others, and determines the Land Capability Classification (LCC; International Resource Panel 2016) for any given LandPKS plot (Table 1).

The LCC was developed by the U.S. Soil Conservation Service (USDA 1961) over half a century ago, but is still being actively used in land use planning efforts globally. The LCC is a system of grouping soils primarily on the basis of their capability to produce crops and pasture without issues of long-term land degradation. Further, LCC was developed because information about the soil must be explained in a way that has meaning to the user, and these explanations are called interpretations. The LCC is one of the many interpretive groupings of soils that can be used to evaluate land for limitations or hazards for producing agricultural crops using soil characteristics (AbdelRahman et al. 2016). The LCC categorizes the land into 8 different classifications based on a variety of factors including organic matter content, texture of the soil, susceptibility of erosion, waterlogging, depth of soil, chemical and physical properties of the soil, and climate (USDA 1961). Among the LCC the first four classes are considered suitable to agriculture, while the last four are better suited to other uses.

LandPKS provides an ideal tool for helping land use planners determine the LCC of a certain site. It is cheap, easy to use, and delivers instant results. Collecting data for one LandInfo plot takes between 15-30 minutes and can unlock the LCC and potential of that land. Collecting LandPKS data at various points within an area may help land use planners determine where the most agriculturally productive land is within that area, and which areas are unsuitable to sustainably cultivate. While simple, obtaining the LCC through the LandPKS app provides valuable information about the potential and limitations of the soil. Such biophysical analysis in land use planning are often not conducted because it is cost prohibitive and communities lack the knowledge and expertise themselves to carry out a traditional soil survey. The use of LandPKS now makes this possible and can provide the basic biophysical characterization through the LCC in order to improve the effectiveness of land use planning.

3.2 Tanzania Case Study

Tanzania provides an excellent example of a country that has ambitious land use planning goals, but often lacks the tools to carry out expensive surveys and biophysical assessments. In this section, we will outline a brief background of land use planning in Tanzania, USAID projects aimed at land use planning and land tenure, and how the National Land Use Planning Commission has proposed to use the LandPKS app and the LCC to assist and improve their land use planning process.

In Tanzania, as elsewhere, most land use planning and management approaches utilized since the colonial period have been 'top-down', and not included full participation from village members (National Land Use Planning Commission 2013). Therefore, in recent years, Tanzania has switched to a participatory land-use management approach, or PLUM. PLUM is advantageous because land use plans are created and implemented by the communities themselves, and therefore reflect their needs and are better adapted to local conditions. Part of the land use planning process often includes greater tenure security for village members. Specifically, the Village Land Act of 1999 provides the registration and issuance of Certificates of Customary Rights of Occupancy (CCROs) as a measure of land security enhancement in rural Tanzania. In order to ensure that village land use plans are technically sound, it is the responsibility of the PLUM team to conduct a systematic assessment of both the biophysical and socio-economic environments. The biophysical assessment refers mainly to the conditions of the natural resources including, climate, soils, hydrology, and vegetation. Part of this assessment may include soils surveys and the use of the LCC (Table 1). The LCC is the preferred method of biophysical assessment because it is simpler than other methods and focuses on the degree of limitations in the land, which are not easily corrected or managed by village members. Environmental policies that must be adhered to in Tanzania during the land use planning and management process include the National Environmental Policy 1997, the National Land Policy of 1995, the National Water Policy of 2002, the National Human Settlements Development Policy 2000, the Environmental Management Act No. 20 of 005, and the Village Land Acts No. 5 and No. 6. (National Land Use Planning Commission 2013).

LandPKS is one potential tool that can be used in Tanzania for carrying out an assessment of the soil and biophysical characteristics. For example, the LandPKS team has been working with the National Land Use Planning Commission as well as USAID's Land Tenure Assistance (LTA) Project to assist in effective land use planning and land tenure efforts. By identifying areas with sustainable agricultural potential through the use of LandPKS, land use planners can integrate biophysical assessments into their participatory land use planning process. The LTA project is helping to revise village-level land use plans. Once land use planning is complete, LTA is using a mobile technology called MAST (Mobile Application to Secure Tenure) to assist village members attain a CCRO (Certificate of Customary Right of Occupancy) for their farms and properties. By integrating LandPKS soil information into their land-use plans, LTA and other land use planners can make better decisions about which areas within a village are suitable for agriculture, and which are not. Focusing agricultural growth on soils suitable for sustainable agriculture not only increases farmer revenues, thus decreasing poverty levels, but also saves other village land for other, less intensive uses such as grazing areas or forest reserves. This type of land-use planning process can and will continue to lead to more sustainable land-use planning and management across the landscape, particularly under global environmental change (Herrick et al. 2016).

Table 1. Land Capability Classes (from National Land Use Planning Commission 2013)

Land Capability Class	Degree of Limitations	Capability	Example
I	Not significant	For all land uses, with normal land management practices	Flat, well drained and fertile lands
II	Little	For all land uses, but moderate conservation practices in case of annual crops	Gently sloping and slightly eroded lands
III	Moderate	For all land uses, but intensive conservation practices in case of annual crops	Sloping and moderately eroded lands
IV	Moderately severe	For all land uses, but annual crops on occasional basis only and with intensive conservation practices	Moderately steep and moderately eroded lands
VI	Severe	For pasture and (semi-perennial) crops with moderate conservation practices and forestry	Moderately steep, stony, and eroded lands
VII	Very severe	For forestry only	Steep, stony, and eroded lands
VIII	Extremely severe	Very extensive utilization only (reserve/wildlife)	Very fragile lands

In Tanzania, the National Land Use Planning Commission, is working with the LandPKS team to implement LandPKS tools in the future for the national land use planning process. Tanzania currently uses a 6-step process for participatory land use management, involving community members and stakeholders at every step. On the biophysical side of land use planning process, Tanzania uses the Land Capability Classification system (LCC; International Resource Panel 2016). LandPKS could play a key role in helping land use planners classify land into these seven classes (Tanzania uses 7 instead of 8 classes). Implementing LandPKS in the land use planning process will simply, and cheaply, help the National Land Use Planning Commission include more biophysical data into their participatory land-use planning process.

The LandPKS team is currently working to develop and deploy the LCC module within the LandPKS app by mid-2018. The LCC module will use many of the already existing user inputs, as well as perhaps a few addition inputs, to help determine the LCC class and deliver that information to the user directly on their phone. The LCC module is being developed for global use, and will be piloted in Tanzania with collaboration with the LTA project and the National Land Use Planning Commission. However, the hope is that the LCC module can be used world-wide in places that need effective and affordable.

4. Next Steps and Conclusions

In this paper, we have: 1. Outlined how LandPKS can strengthen and enhance sustainable land use planning and land management, and 2. Provided evidence for this through case studies in Tanzania. Through the use of innovative mobile tools such as LandPKS, the cycle of land degradation and increased poverty can be reversed. Through sustainable land use planning and management, land can become a springboard for those in poverty to improve their socio-economic condition. By being able to practice livelihood strategies that are appropriate for the biophysical conditions, sustainable land-use planning and land management improves both environmental conservation and increases incomes for the poor. Lastly, effective land use planning through the LandPKS app can help address many the 2030 SDGs and be used globally for more efficient, sustainable land use and management. LandPKS is one tool for more effective, affordable, and socially just land use planning.

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