ProvidingAssessable Soil Information: A Case of the Land Potential Knowledge System (*Land*PKS) in Benue State, Nigeria

Abstract

The extension-farmer ratio gap is at an all-time high with extension workers rarely equipped to provide farmers the needed information and tools to better manage their farm fields. Soil health is critical to achieving food security sustainably. Soil management practices will enable small holder farmers increase productivity amidst a changing climate and an increasing population which puts pressure on natural resources. The Land potential knowledge system (Land*PKS* version 3.77 for Android and 3.71 for iOS) mobile application was used for on- the- spot- assessment of soil potential at Agan council ward of Makurdi Local Government area (LGA) in Benue State. This pilot study entailed purposeful selection of 10 farmers and their farm fields in Agan council ward Makurdi LGA. The Land PKS is a new innovative technology that provide information on soils using mobile phones and also gives spatial data on land use, land capability classification and management. Chemical properties of the soil were read *insitu* with a sensor machine using the principle of internet of things (IOT) and some soil properties were analyzed for in a Soil laboratory. Findings here reported are location specific. Soils at the surface were mostly sandy while the subsurface varied from sandy clay loam to clay with moderate acidic and low nutrients (Nitrogen and Organic carbon). The LCC class for the area indicates limitations that can impact on agricultural productivity and the environment. The Land PKS mobile application will serve as a soil management tool for extension workers while providing data needed for making critical decisions on government bulk fertilizer purchases.

Keywords: Extension worker, IOT,Land PKS,Mobile Application,Soil Data, Soil Health

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1.0.Introduction

The continued growth of agriculture, over the last couple of years has come from land expansion rather than increased productivity per unit area of their farm fields (Snapp 1998)..Achieving food security amidst increasing population will stem from agricultural intensification rather than land conversion for production. This would require timely knowledge of land potential to support decision making.Building the capacity of farmers with information via modern technology will get them better equipped to innovate and change their land potential by carrying out on- farm practices that would increase agricultural productivity while minding land resilience to changing climatic conditions. (Kwadwo Asenso ,2009).

There has been growing expansion of smart phones and internet accessibility through mobile phone service providers together with simple mobile applications which provides new opportunities to connect farmers, extension workers, development planners, and policymakers with site-specific knowledge and information on land potentials. Leveraging on this new technological trend, The Land-Potential Knowledge System (LandPKS) presents a suite of mobile apps allowing individuals and organizations to use their mobile phone to determine the land potential of a specific location based on local and global knowledge and information (Herrick *etal*., 2016; Quandt*et al.*, 2018; 2020). This interactive application will serve as a soil health management tool in the hands of extension workers farmers,students and land users generally providing on- the- spot assessment of land biophysical properties(Irkiso et al. 2020; Sepehya et al 2024). This point/ specific management will impact on transitioning from conventional farming to precision agriculture which is largely data driven (Herrick *et al.,* 2016). The LandPKS includes 4 modules that allows virtually anyone with a cell phone (Android or Apple) to easily and rapidly (a) contribute to global data-and knowledge-bases, and (b) use the same data to adapt to their own management. Outputs from the Land Infomodule for instance, includes soil identification (from NRCS Soil Survey and global maps) and calculated plant available water holding capacity, infiltration capacity, and Land Capability Class (LCC). These outputs are based on user inputs for location, soil texture, color and slope (Herrick *et al*., 2019). The appropriate matching of land use with land potential needs accurate, site-specific knowledge of land, including but not limited to information on its long-term potential (based on inherent properties like texture, mineralogy, and slope), current condition (e.g., fertility, soil organic matter content, vegetation cover), and expected response to disturbances (e.g., management, climate). When such information and knowledge is lacking amongst land managers, they are less likely to make informed management decisions that would otherwise ensure long-term sustainability. To bridge this information gap, the Land Potential Knowledge System mobile application (LandPKS) was created with the goal of providing location-specific information on land potential that farmers and other land managers can use to make informed management decisions (Herrick *et al.,* 2013; 2016). This tool will aid technology driven farming at minimal cost. An overview of the LandPKS mobile application has been well captured by Quandt*et al*.(2018). Practical tips and videos on how to download the application and its use can be found at the website However, awareness of the availability of this free, open-source mobileapplication with access to both US and global soil information remains low. Hence the need for training of ministriesof agriculture staff at both state and federal levels on its use following pilot testing at Agan a council ward location in one of the USAID Feed the Future Nigerian Agricultural policy Project (NAPP) Focal States. Reports here presented are findings at Agan during the pilot testing. This has given room to more detailed trainings on the use of LandPKS mobile application for farmers, extension workers, students and Faculty members of research institutions in other states in Nigeria (Kebbi, Benue, Kogi and Ebonyi) respectively.

1.1. The objective of the study

1. To use the Land PKS mobile application as a tool to access the land potential of smallholder farmers' fields and serve as a management tool in the hands of farmers, extension workers and land managers.
2. Create awareness and build capacity of extension workers and farmers on the use of the Land PKS application in Focal USAID Feed the FutureNigerian Agricultural Policy Project (NAPP) states and other states, geared towards transitions to precision agriculture.

2.0. Methodology

2.1 Working Principle of the Land PKs

The LandPKS mobile application (http://landpotential.org) seeks to provide individual users with point-based estimates of land potential based on the integration of simple, geo-tagged user inputs. This data, information, and knowledge is stored in the cloud see (Fig.1). LandPKS users, provide site-specific land cover and soil profile information using primarily icon-based inputs. Short, animated, language-independent tutorials for determining soil properties are also embedded in the mobile phone application. Users simply select the image that most closely look like what they see.

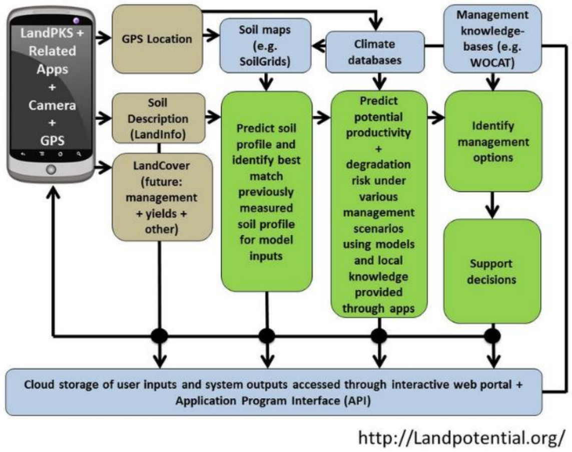


Fig 1. Flow chart of the LandPKS mobile application.
Source Herrick*et al*. (2016)

These user inputs are uploaded automatically from the mobile phone to cloud the next time the phone has data access. The inputs are stored on remote servers and integrated with global climate and soils databases (e.g., SoilGrids), which then provide inputs for predictive models.

2.2. Study Area

Agan is a council ward in Makurdi Local Government Area (LGA) of Benue state, Makurdi is located between latitude 7.732152˚N and longitude 8.39144˚ E in the Southern Guinea Savannah of Nigeria. A council ward in Benue state having a tropical sub-humid climate, with two distinct seasons, namely wet and dry season. The wet season which last for seven months normally starts from April and end in October. There is, however, usually one or more heavy out of season rains in January, February and/or March. The soils are predominantly Alfisols and Ultisols (tropical ferruginous) which vary over space with respect to texture, drainage and gravel content. A typical profile is highly weathered with a sandy surface layer overlying a clay mottled subsoil.In the past, Benue state experienced a bimodal rainfall distribution pattern with one peak in July and another in September. However, recent meteorological data (2008 - 2010) indicate uni-modal pattern with the peak in August. The mean annual rainfall ranges between 1200 – 2000mm (Nigerian Meteorological Agency Headquarters Makurdi Airport). Persistent clearance of the vegetation has led to re-growth of new vegetation at various levels of development;however, the grasses grow very tall with scattered trees mainly of economic values such as locust beans, shear butter, mango, silk cotton, African iron, *Isobelinia*, cashew, oil palms, *Danielliaoliveri*, *Gmelina arborea*. The locations used for the pilot study were selected farmer's field with the following geo- coordinates Lat.7.83027 Long. 8.57533; Lat. 7.83055, Long. 8.57524; Lat. 7.83087, Long. 8.57515; Lat.7.83143, Long, 8.57412; Lat.7.83162, Long. 8.57401; Lat. 7.83210, Long. 8.57355; Lat.7.83176, Long.8.57258; Lat.7.83131, Long.8.57247; Lat. 7.83089, Long. 8.57232; Lat. 7.82723, Long. 8.57689respectively.

2.3. Data collection

This pilot study entailed purposeful selection of 10 farmers and their farm fields in Agan council ward Makurdi LGA, Criteria for selection was a field between 0.5 to 2 hectares grown to maize following farmer's practices and cropped for over 5 years with the farmer or his ward, possessing an Android phone. These ten (10) farmers were a subsample of 300 farmer households under the study.Structured questionnaire was also administered to each farmer to get their knowledge on soil management practices and their perception on the use of the mobile application. Before the field pilot testing, a five-day rigorous training was offered to the participating undergraduate and graduate research students of the Soil Science Department of Joseph Sarwuaan Tarka University Makurdi who were part of the project. Soil profile pits were dug, three in each farmers plot. Soil samples were collected at specified depths at 10cm increments for the LandPKS and 30cm for the Soil Productivity Index rating project (not reported here). Soil pH was read with a sensor device i*nsitu* in the field while other chemical properties were analyzed in the Laboratory. Only pH and Nitrogen are reported here. Statistical analysis of data was carried out using R programming language version 4.0. Descriptive statistics was used to analyze the data from the administered questionnaire.

3.0. Results and Discussion

3.1. Feedback from farmers

Overall, 10 responses were collected from the farmers on their experience with using the LandPKS mobile application. They farmers were asked how easy they found the use of the LandPKS application. 80 percent of the farmers agreed that LandPKS mobile application was easy to use, given the pictorial prompts and detailed guiding documentation in simple language Fig. 2. They were also asked if they had received prior advice on how to manage their soil to which a great majority (60%) said no see Figure 3 and a few said yes this has implications on how farmers were well informed by government extension workers on soil management practices for improved production sustainably and in mitigating climate change issues. On another question, the farmers were asked the distance of their homestead to an advisory services station from a government extension worker. Figure 4 depicts responses obtained. The LandPKS mobile application would bridge this gap as information on climate, soil texture, color, topography, available water content (AWC) and organic matter, can be accessed with the click of a button and records kept for each farmer.

Figure 2: Farmers perception on using the LandPKS mobile application

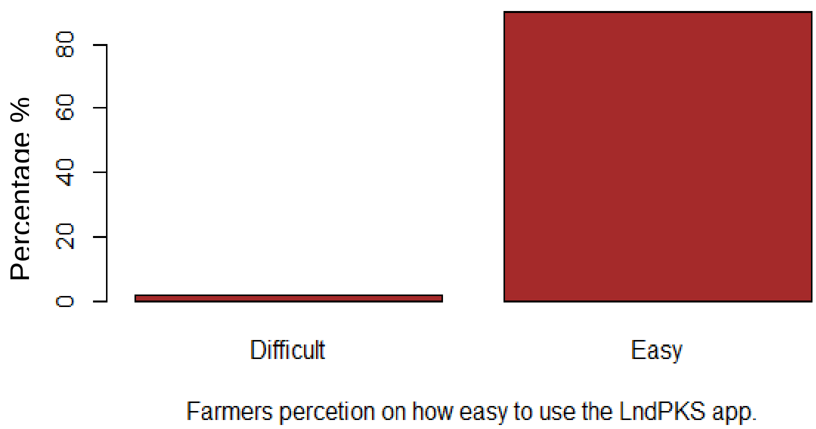


Figure 3: Number of farmers who received any advice on how best to manage their soils

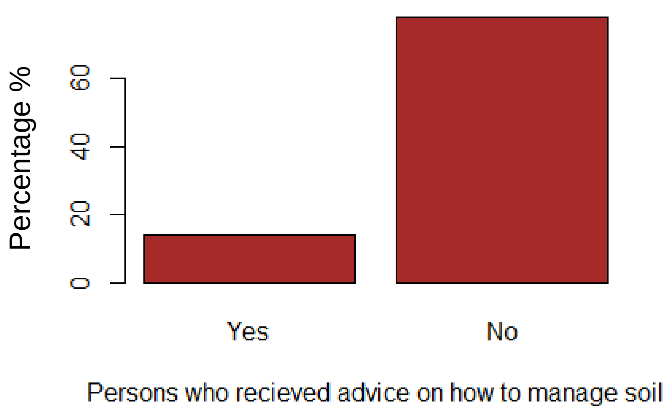
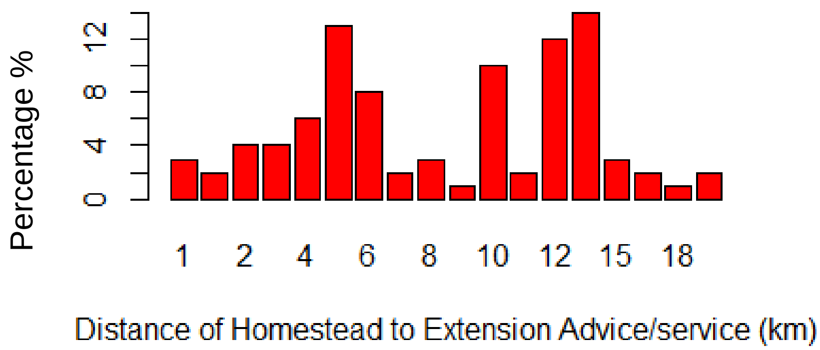


Figure 4: Distance of Extension worker to farmers residence



3.2. Laboratory Analysis

3.2.1. Nitrogen

Nitrogen values are reported in Table 1. The values range from 0.012% to 0.14%. Nitrogen is very low in these soils. This may be due to high leaching, mineralization or pH interfering on soil microorganisms that aid nitrifying bacteria. Nitrogen content was more at the top soil and decreased consistently as the depth increased this is in agreement with earlier findings by Lamb *et al*. (2014) .The report here is an abridged version, the full dataset was used in creating the first digitalized and interactive Soil Nutrient and Soil Productivity for Benue state see link: https://rb.gy/l3si6h

3.3pH readings with a Sensor Device

The pH values ranged from 3.47 acidic to 6.92 slightly acidic. Severe soil acidity is not a major problem in the smallholder farm fields under study. (Table 1) except for isolated cases. This supports earlier studies wheresoil pH was slightly acidic, (Okloet *et al.*, 2021) this is attributed to the accumulation of H+ and Al3+due to poor farm practice. Nutrients availability is greatly influenced by pH levels, nutrients are most available to plants in optimum pH range of 5.5 - 7.5. The values obtained were consistent with those obtainable from laboratory analysis in water. The values obtained from the individual farmer's field shows high variability, hence the need for site specific management.

Table 1: Abridged Chemical Properties of Soils under Study

Depth(cm)	(%)Nitrogen	pH
0-30	0.12	3.67
30- 60	0.01	6.85
60-90	0.01	2.99
0-30	0.14	6.44
30- 60	0.02	6.8
60-90	0.01	6.92
0-30	0.09	6.32
30- 60	0.04	5.79
60-90	0.01	4.52
0-30	0.11	6.74
30- 60	0.07	5.79
60-90	0.012	4.52
	Max(0.14) Min(0.01)	Max(6.92) Min(2.99)

3.4.LandPKS mobile application generated results

3.4.1.Climate

The climate report varied across locations.Actual monthly precipitation ranged from 2 – 254 (mm) with monthly peaks in August and September for all the location. The average annual precipitation ranged from 1240 to 1355(mm) seeTable 2 for a sample from one location as generated by the LandPKS mobile application**.**Average temperature ranged from 26 to 30^{0}C**.** The aridity index ranged from 0.7372 to 0.7376 while length of growing season ranges from 210 to 239 days.

Table 2: Generated Climate Report from theLandPKS Mobile Application

Average Annual Precipitation (mm): 1355

Average Monthly Precipitation (mm) and Temperature (°C) :

Month	Precipitation	Average Temperature	Minimum Temperature	Maximum Temperature
January	2	27	19	34
February	2	29	22	37
March	33	31	25	37
April	83	30	25	35
May	156	28	24	33
June	199	27	23	31
July	228	26	23	30
August	245	26	23	30
September	254	26	22	31
October	146	27	23	32
November	6	27	21	34
December	0	26	18	34

Growing Period (days/year): 210-239 Days

Aridity Index: 0.7372

3.4.2.Soil Characteristics

Surface texture (0-1cm) depth, was sand in all location. Snapp (1998), reports that these kinds of soil will have high water and Nitrogen losses. Thesoil color at the surface was 5YR3/7 using the Munsellcolor chart imbedded in the LandPKS mobile application. This has implications for farmers to know soils rich in organic matter as given by the darker color.At lower depths, the texture was loamy to sandy loam (20 – 50cm) while at (70- 100cm) textual class was sandyclay loam and clay mostly. Surface infiltration ranged from 60 – 105 mm/hr. while available water content (AWC) at 20cmdepth, ranged from 0.8 to 0.9 cm whileit ranged from 6.2 to 11.2 cm at 1 m depth.This has serious implications for farmers because the field with higher available water, will be generally more productive due to its greater ability to hold water in the soil for crops to utilize. (Quandt*et al*., 2018). The point-based model used by LandPKS is very powerfulemphasizing that location is important in any fertility management as soil varies significantly from place to place these changes in soil types can have dramatic impacts for farmers and others aiming to utilize that land. Organic matter prediction was onepercent for all location. This value is sufficient to support crop production and prevent soil degradation (Pieri, 1995) to an extent, however, for higher yields three (3) percent organic matter is requiredMusinguzi et al.(2016). Find the results for individual location characteristics at the LandPKS data portal https://portal.landpotential.org/#/landpksmaps

3.4.3.Land Capability Classification (LCC).

The LandPKS mobile application serves as a tool that informs better sustainable land use planningand management. The LCC is a global evaluation ranking, whichgroup's soils based on their potential for agricultural and other uses. LCC can help determine if land is suitable for certain uses and whether there are risks for degradation. Result generated showed that soils were in the severe limitation class that limits choices of plants andrequireconservation practices i.e.LCC Class 3 with other subclasses indicating other limiting factors. A few LCC values read: 3s-a, w-d; 3sd-s-a,w-f,w-d; 3s-d.s-r.s-a.w-d for three location respectively. Results of all the other sites geo referenced and point based can be found https://portal.landpotential.org/#/landpksmaps

4.0 Conclusion

Soils at the surface were mostly sandy while the subsurface varied from loamy to sandclay loam and clay withmoderate acidic and low nutrients (Nitrogen and Organic carbon). This is inadequate to increase productivity and maintain soil structure given high intensity rains (Agada *et al.*2016). The LCC class for the area indicates limitations that can impact on agricultural productivity and the environment if the soils are not managed properly given largevariability. Conservation practices such as reduced tillage, mulching, tied ridging are suggested. The Land PKS mobile application, is one tool which can be used to expand our knowledgeof land potential and used as a soil health management tool with implication on site specific land use, fertilizer use, food security and both climate adaptation and mitigation activities at minimal cost to the farmer and other land users.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

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Appendix

LandPKS mobile application display of one of the location at Agan Council ward