

# **Providing Assessable Soil Information: A Case of the Land Potential Knowledge System (LandPKS) in Benue State.**

## **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 (LandPKS) 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:** Soil health; Land PKS; Soil Data; Mobile Application and IOT; Extension worker.

## 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. 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.

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 *et al.*, 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. 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 [www.landpotential.org](http://www.landpotential.org). However, awareness of the availability of this free, open-source mobile application with access to both US and global soil information remains low. Hence the need for training of ministries of 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 Future Nigerian Agricultural Policy Project (NAPP) states and other states, geared towards transitions to precision agriculture.

## **2.0. Methodology**

### **2.1. 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 HQtrs 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.

## **2.2Data 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 *insitu* 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.

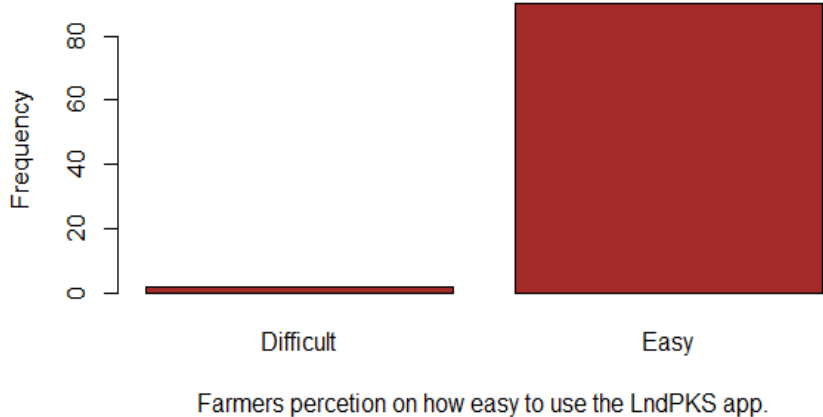
## **3.0. Results and Discussion**

### **3.1.Feedback from farmers**

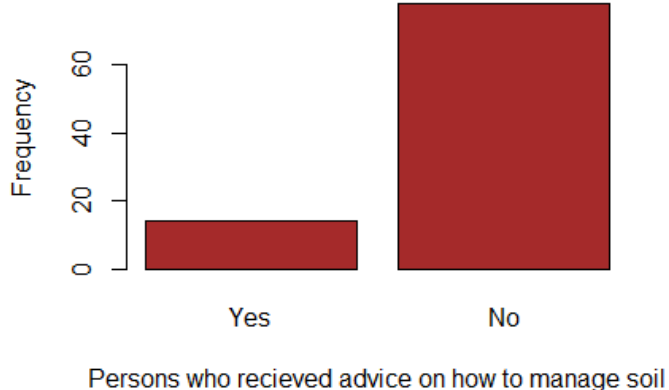
Overall, 10 responses were collected from the farmers on their experience with using the LandPKS mobile application. They farmers were asked how easy they found the use of the LandPKS application. 80 percent of the farmers agreed that LandPKS mobile application was easy to use, given the pictorial prompts and detailed guiding documentation in simple language. They were also asked if they had received prior advice on how to manage their soil to which a great majority said no see figure 2 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 3 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.

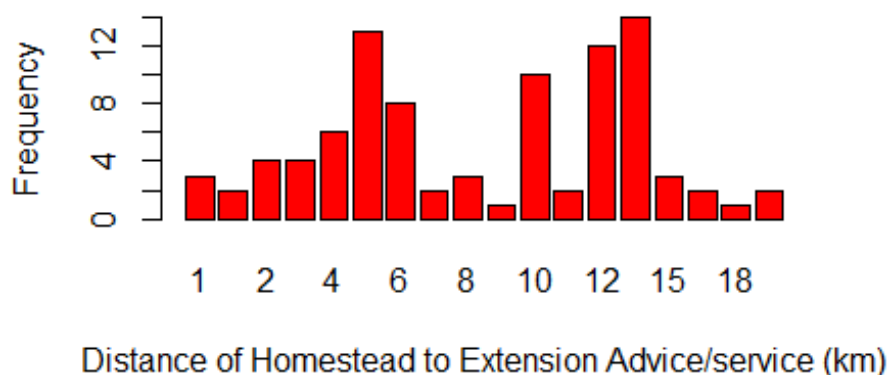
**Figure 1:** Farmers perception on using the LandPKS mobile application



**Figure 2:** Number of farmers who received any advice on how best to manage their soils



**Figure 3:**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>

#### 3.3 pH 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 where soil pH was slightly acidic, (Okloet *et al.*, 2021) this is attributed to the accumulation of H<sup>+</sup> and Al<sup>3+</sup> 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) see Table 2 for a sample from one location as generated by the LandPKS mobile application. Average temperature ranged from 26 to 30<sup>0</sup>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 the LandPKS 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. The soil color at the surface was 5YR3/7 using the Munsell color 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) textural class was sandy clay loam and clay mostly. Surface infiltration ranged from 60 – 105 mm/hr while available water content (AWC) at 20 cm depth, ranged from 0.8 to 0.9 cm while it 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 powerful emphasizing 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 one (1) percent 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 required Musinguzi 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 planning and management. The LCC is a global evaluation ranking, which groups 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 and require conservation 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 Summary and Conclusion**

Soils at the surface were mostly sandy while the subsurface varied from loamy to sandclay loam and clay with moderate 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 large variability. 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 knowledge of 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.

### **Declaration**

**Consent for publication:** The article contains no such material that may be unlawful, defamatory, or which would, if published, in any way whatsoever, violate the terms and conditions as laid down in the agreement.

**Availability of data and material:** Not applicable.

## References

Agada, B.I., Obi, M.E., Ali, A. (2016). Rainfall Characteristic at Makurdi-North Central Nigeria II. International Journal of Science and Technology (STECH) Vol. 5 (1) 40-46. In: [Rainfall Characteristics at Makurdi, North–Central Nigeria II \(researchgate.net\)](#) .

Herrick, J. E., Urama, K.C., Karl, J.W., Boos, J., Johnson, M-V.V., Shepherd, K.D., Hemple, J., Bestelmeyer, B.T., Davies, J., Guerra, J.L., Kosnik, C., Kimiti, D.W., Ekai, A.L., Muller, K., Norfleet, L., Ozor, M., Reinsch, T., Sarukhan J., and West, L.T. (2013). The global Land-Potential Knowledge System (LandPKS): supporting evidence-based, site-specific land use and management through cloud computing, mobile applications, and crowdsourcing. *Journal of Soil and Water Conservation* **68**: 5A–12A.

Herrick, J.E. Edmundo B.A., Barrios, B. I., Coetzee, M., Dent, D., Elias, E., Hengl, T., Karl, J.W., Liniger, H., Matuszak, J., Neff, J.C., Ndungu, W.L., Obersteiner, M., . Shepherd, K.D., Urama, K.C, Rik van den Bosch, Webb, N.P. (2016). The Land-Potential Knowledge System (LandPKS): mobile apps and collaboration for optimizing climate change investments. *Journal of Ecosystem Health and Sustainability* Vol. 2; Issue 3 In: [The Land-Potential Knowledge System \(LandPKS\): Mobile apps and collaboration for optimizing climate change investments \(researchgate.net\)](#)

Herrick, J. E., Amede, T., Bestelmeyer, B., Buenemann, M., Buni, A., Desta, L., & Wills, S. (2019). Landpks: Mobile App for Participatory Soil Health Research, Innovation and Monitoring. In *ASA, CSSA and SSSA International Annual Meetings (2019)*. ASA-CSSA-SSSA.

Irkiso A., Abebe B.T., Hadgu K. and Abza G.T. (2020). Pilot Testing LandPKS smartphone application for local level participatory land use planning in Ethiopia.. Available from: [https://www.researchgate.net/publication/346394015\\_Pilot\\_Testing\\_LandPKS\\_smartphone\\_application\\_f\\_or\\_local\\_level\\_participatory\\_land\\_use\\_planning\\_in\\_Ethiopia](https://www.researchgate.net/publication/346394015_Pilot_Testing_LandPKS_smartphone_application_f_or_local_level_participatory_land_use_planning_in_Ethiopia).

Lamb, J.A., Fernandez, F.G., Daniel, E. and Kaiser, D.E. (2014). Understanding nitrogen in soils. University of Minnesota, USA.

Musnguzi, P., Ebanyat, P., Tenywa, J., Basamba,T., Tenywa, M.,& Mubiru, D. (2016). Critical Soil Organic Carbon Range for optimal crop response to mineral fertilizer Nitrogen on a Ferralsol. *Experimental Agriculture*, 52(4) 635-653.doi:10.1017/S0014479715000307.

Oklo, A.D., Armstrong, I.A., Idoko, O.M., Iningev, T.S., Emmanuel, A.A. and Oklo, R.O. (2021) Assessment of Soil Fertility in Terms of Essential Nutrients Contents in the Lower Benue River Basin Development Authority Project Sites, Benue State, Nigeria. Open Access Library Journal, 8: e7222. <https://doi.org/10.4236/oalib.1107222>. Available from: [https://www.researchgate.net/publication/350550733\\_Assessment\\_of\\_Soil\\_Fertility\\_in\\_Terms\\_of\\_Essential\\_Nutrients\\_Contents\\_in\\_the\\_Lower\\_Benue\\_River\\_Basin\\_Development\\_Authority\\_Project\\_Sites\\_Benue\\_State\\_Nigeria](https://www.researchgate.net/publication/350550733_Assessment_of_Soil_Fertility_in_Terms_of_Essential_Nutrients_Contents_in_the_Lower_Benue_River_Basin_Development_Authority_Project_Sites_Benue_State_Nigeria).

Pieri, C (1995). Long term soil management experiments in semi-arid Francophone Africa. Pp. 225-266. In: R Lal and B.A. Stewart (eds.), Soil Management Experimental Basis for Sustainability and Environmental Quality. Advances in Soil Science, CRC Lewis Publishers. Boca Raton, Fl.

Quandt, A., Herrick, J.E., Peacock, G., Salley, S., Buni, A., Mkalawa, C.C. and Neff, J. (2020). A standardized land capability classification system for land evaluation using mobile phone technology. Journal of Soil and Water Conservation.

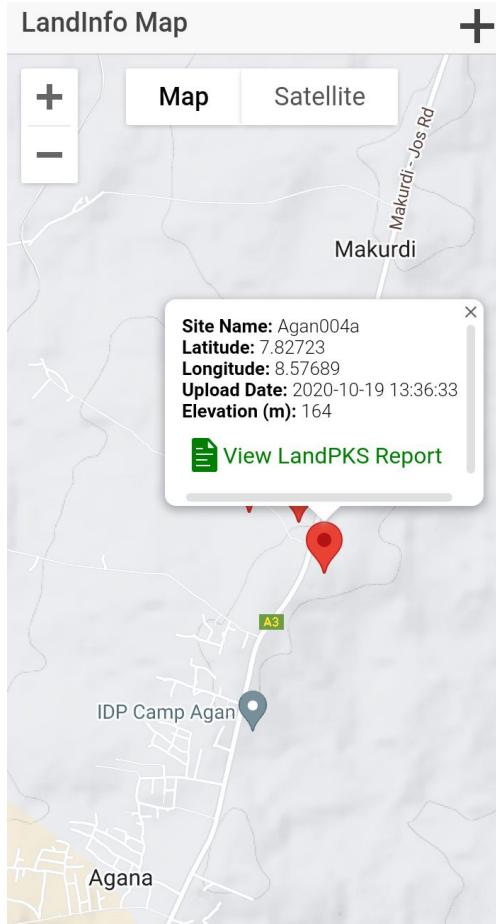
Quandt, A. (2018). [Location Matters! LandPKS Can Provide Point-Scale Soil Information | LandLinks \(land-links.org\)](https://land-links.org).

Quandt, A., Herrick, J., Bouvier, I. and Peacock, G. (2018). LANDPKS: A NEW MOBILE TOOL FOR SUSTAINABLE LAND-USE PLANNING AND MANAGEMENT. In: World Bank Conference on Land and Poverty. [online] Washington DC: World Bank. Available at: [https://www.researchgate.net/publication/325131011\\_LANDPKS\\_A\\_NEW\\_MOBILE\\_TOOL\\_FOR\\_SUSTAINABLE\\_LAND-USE\\_PLANNING\\_AND\\_MANAGEMENT/stats](https://www.researchgate.net/publication/325131011_LANDPKS_A_NEW_MOBILE_TOOL_FOR_SUSTAINABLE_LAND-USE_PLANNING_AND_MANAGEMENT/stats).

Snapp S.S. (1998). Soil Nutrient Status of Smallholder Farms in Malawi. COMMUN. SOIL, SCI. PLANT ANAL. 29(17&18), 2571-2588(1998).

## Appendix

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



UNM