The Importance of ‘Where’ in Revitalization Strategies for Nepal:

PART 4: ZEROING IN ON FARMERS’ FIELDS

ASIA’S PATH FORWARD

By Indra Sharan KC & Paul Lundberg | 21 October 2020
SUMMARY

The COVID-19 pandemic and its aftermath may have a transformational impact on the Nepali economy. Both government and non-state actors have recognized the important role of digital data technology in Nepal’s future economy. However, much of the accessible data remains scattered, generalized, and often inaccurate. This series discusses how a three-pronged approach can contribute to an inclusive recovery in Nepal: 1) Improve government willingness to openly share digital data with citizens, 2) build a location centered information base to support market systems development, 3) foster the creation and maintenance of a shared data ecosystem involving citizens and local governments.

Throughout this series, we kept returning to the question of what can be done to help individual farmers. This fourth piece adds more details to our introduction to affordable drone mapping technology presented at the end of Part 3. Following an introduction to the government’s property tax system, this article describes a private exercise to map a farm village in Nepal using drone imaging technology. Conclusions are drawn on the use of the information generated to aid in rural economic revitalization. This technology can be used easily and cheaply by citizen scientists to help Nepali farmers create a detailed information base about their property that can be used to improve their understanding of land capacity and income generation potential. At the end, we suggest how this technology can be incorporated into other ongoing programs.

BACKGROUND

Over 70% of the Nepali population depends on agriculture, yet less than 30% of Nepal’s territory is cultivable. Clearly, paying close attention to improving small farm productivity needs to be a core element of any economic revitalization strategy in Nepal. However, supporting farmers to use existing technology will not be sufficient. Generations of inheritance within densely packed farm communities has resulted in serious land fragmentation, resulting in many small plots scattered far from each other.

1 Small farm strategies are also being promoted in developed countries as a means of reducing stress on the environment. https://smallfarmfuture.org.uk/my-book/


As noted in Part 3, the wealth of rural families is directly correlated with the size, quality, and location of their land. Many marginalized groups are left behind due to lack of land or lack of rights to use the land they have.

Existing cadastral and topographic maps were generated by government agencies to enhance the power of the state. Generations of Nepali farmers have used their accumulated knowledge to make important decisions at the farm and household level. The information generated by incorporating modern technology into this process could create a new land management paradigm in Nepal with the potential to improve the productivity of land use by minimizing land fragmentation and promoting land consolidation.

Citizen scientists in many parts of the world have shown mapping individual farm properties can enhance our understanding of land management and improve policy analysis. Large-scale property mapping generates accurate information on land area, spatial distribution of land plots, contiguity of land parcels/plots, land use, crop types by season, proper scientific classification of land plots, and micro-terrain information at the farmers' level. All this assists in the development of better land management policies for improving land productivity, saving land from un-productive conversion and land fragmentation, planning better farming practices, estimating agricultural inputs accurately, public understanding of unequal land distribution, and developing better policies for access to land for marginalized and landless communities.

GOVERNMENT CADAstral MAPPING

The maps of Nepal's national land resource and topographic series are prepared by the government at a scale that is suitable for central planning only. While these maps appear accurate at a national scale, they contain serious distortions and lack important information for local planning. The first land resource maps to cover the entire country were produced in the 1980s. These provided the first detailed approximation of land use, settlements, and infrastructure. However, they were unable to

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2 A topographic map depicts a country's general elevation trends, infrastructure, settlement, and vegetation distribution patterns. A cadastral map, typically of much larger scale, is used to show the shape, size, and boundary of land properties.

3 Citizen science is the practice of public participation and collaboration in research by knowledgeable individuals. Through citizen science, people share and contribute to data collection and monitoring programs. Usually this participation is done as an unpaid volunteer. Goodchild MF. Citizens as sensors: the world of volunteered geography. GeoJournal. 2007;69:211.

4 Nepal's Land Resources Mapping Project's 1:50,000 scale maps initiated in early 1980's were first such maps covering the country.
capture land surface information in enough detail to fully present the holistic relationship of a household with its land. 

The Nepali government also prepares large-scale cadastral maps for urban, peri-urban and rural areas to register land ownership certificates used to determine the land tax owed by the landowner. Owing to the cumbersome technology used to prepare these maps, they are updated only infrequently. As their primary purpose is to guide tax collection, they do not provide land use details or proper land classification of the individual plots. Obtaining access to cadastral information is difficult. Although technology exists for providing full access to cadastral information via internet or mobile phones or on internet platform, even obtaining an official printed map of one’s own property requires a long bureaucratic process.

Government has plans to modernize the land cadastral system. Country-wide cadastral mapping with analog technology in a mountainous country invariably allows for the introduction of many errors. Some attempts have been made to match up cadastral maps to new satellite imagery. However, no matter how fine the resolution, satellite imagery does not provide sufficient detail for accurate mapping and measuring of farmland properties in Nepal. The plots are too small, and there is mixed land use within small land plots.

In 1977, one of the co-authors, while a teenager, watched the government prepare a cadastral map of his village. More than two decades later, that map had not been updated, so he attempted to match the government cadastral boundaries with spatial reality via available high-resolution satellite imagery. In 2000, he helped Kathmandu Municipality build a land information system for integrated tax collection. In both cases, he observed that the parcel boundaries align poorly with actual features on ground, especially given the rapid changes in urban areas due to construction and rapid land sales. Nevertheless, these parcel records are tied to the landowner, the stated land area, and an outdated land classification system, which remain the legal basis for all land transactions. (see Figure 1)

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Figure 1 Government Cadastral Map Boundaries overlaid on a Satellite Image

MODERN AERIAL MAPPING

In this section, we will present an experimental procedure used to map a village in the western mid-hills to create accurate farm property and micro-land use information base for an entire rural community. The test area was the village of Kaminthumka in Pawai Gamde Ward 5 of Putalibazar Municipality, with 17 households and 25 hectares of land. Some members of this village have worked in the Middle East, but returned with their savings to expand their family businesses. Other have moved to nearby Pokhara Town yet maintain agricultural practices they had been following for generations. However, the amount of fallow land is increasing as many of the village youths are now working in cities in Nepal and abroad.

The images were generated following a series of unmanned aerial vehicle (drone) mapping missions in

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7 All of the following figures were generated by the co-author, Indra Sharan K.C., in his personal capacity.

8 An unmanned aerial vehicle (UAV) (or un-crewed aerial vehicle, commonly known as a drone) is an aircraft without a human pilot on board. UAVs and their GPS navigation systems were originally used by the military. Now, they are becoming common in civilian and government use and are used for aerial surveys, mapping, photography, transporting goods and medical supplies to remote areas.
2018 and 2019. The images were shown to the villagers, who immediately identified their own and neighboring lands. They also identified different fodder trees and cash crops interplanted with the staple, millet (kodo). The experiment showed that villagers required little guidance to accurately plot out their own land parcel boundaries and add critical features of their lands. Figure 2 is an image map on which family members identified plots and helped draw the boundary lines. The large plot of land is owned by many farmers. One can see the man-made temporary boundary lines, delineating land being prepared for winter vegetable plantation. The dotted lines are added as boundary lines based on the interpretation by the farmers who live nearby the property. The value of land which is hand-sculpted by farmers cannot, by definition, be limited to a sketch on a cadastral map for taxation only. It holds other values and properties such as housing for people, shade and fodder trees for animals, walk-ways to interact with the land, and plants to sustain a rural way of life. The value of rural land must be considered more holistically.

**Figure 2** A simple aerial image of Kaminthumka Village, Syangja District showing farmer demarcated land ownership boundaries.

**WORKFLOW FOR FARM PROPERTY MAPPING**

There is a well-defined workflow for drone mapping of farm properties. Each step is given below and described in brief. The initial mapping process for Kaminthumka Village took 15 minutes of mission planning and 25 minutes of flight time for a consumer drone to take 250 images at a flying height of 300 feet.
The following are the critical steps that need to be taken:

**Authorization:** As per the law, one must obtain appropriate flight permission from the Civil Aviation Authority of Nepal (CAAN), as well as from security and local authorities for the drone survey.9 10

**Selection of area:** The farmers and land must be identified and the area to be imaged needs to be calculated using available maps and images (such as Google Maps). The area covered by the drone flight consists of land belonging to many farmers, so the entire community or village should be involved.

**Mission planning:** Once the area for mapping is identified, a map of the flight plan is prepared using an appropriate application, usually on a mobile phone. The area is drawn on the map, and based on flight and camera parameters, the app computes the number of flight lines, flight height, number of photos and duration of flight and amount of power on battery. (see Figure 3)

Figure 3 The Drone and its Flight Plan

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9 Civil Aviation Authority- [https://caanepal.gov.np/drone](https://caanepal.gov.np/drone)
The drone used in this case was a DJI Phantom 4 Pro, a consumer drone. The flight planning and data acquisition was done on the Drone Deploy mobile application. In Nepal, the use of drones became prominent in the aftermath of the 2015 Gorkha Earthquake. Drones were used to map settlements for damage assessment. Drones fall under the category of either (a) special purpose (b) professional (c) consumer, or (d) play drones. Cost of the drones varies by the category. However, their costs are dropping quickly. The Nepali Government has introduced strict regulations for the use of drones, but this has not stopped their growing use.

**Data acquisition:** The mission plan is fed into the UAV, and the UAV is given a command to fly the designated flight path. UAV captures imagery at pre-determined intervals from a fixed height. The images are geo-tagged by the GPS in the device and stored on its metadata (EXIF)\(^\text{11}\) file. The UAV returns to its original position after executing the data acquisition task. Image taking may be repeated to capture seasonal variation in land use and for clarity of land boundaries.

**Establish Control points:** For small, reasonably flat areas, the image created using the geo-tagged image map is accurate enough for mapwork. However, for extended surveys of large areas and where the terrain is rugged, it is recommended that ground control points be collected for geometric correction. Either Real Time Kinematic (RTK) or Post Processed Kinematic (PPK) systems can be integrated with the imagery to eliminate the need to collect ground control points.\(^\text{12}\)

**Generation of ortho-rectified products:** The images captured and stored on the memory card are downloaded for processing on a desktop computer or on a cloud platform. Specialized software is used to apply photogrammetric techniques to process the images and ground control points to generate ortho-image maps, digital surface models, point cloud data and other optional products. These products are then used in various applications.

The images were uploaded in Pix4D cloud. The image processing on the cloud platform took about 3 hours including wait time. Design of a cartographic ortho-image map took only two hours. The processed ortho-rectified image mosaic, DSM (Digital Surface Model) and point-cloud data were made available by Pix4D within couple of hours.

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\(^{11}\) EXIF stands for EXchangeable Image file Format, which is a standard that defines the formats of image, audio, and metadata tags used by cameras, phones, and other digital recording devices.

\(^{12}\) [https://dronedj.com/2019/03/18/phantom-4-rtk-replacing-gcps-drone-mapping/](https://dronedj.com/2019/03/18/phantom-4-rtk-replacing-gcps-drone-mapping/)
Analysis: Depending on the objective, interpretation and analysis are conducted as necessary. Strategic information and terrain analyses are produced to support the farmer.

DSM data was used to carry out terrain analysis. Slope and contours were calculated. Profile graphs were plotted for a small area that consisted of recently harvested rice fields. The profile clearly showed the flat paddy fields and the sloping sides of the fields. The volume of the harvest was also calculated without any difficulty. Vertical measurements on the point-cloud data with image texture were carried out on buildings and trees. Building dimensions, fodder tree height and crown area, height of agricultural terraces and their slopes, small depressions could all be reckoned quantitatively.

Participatory image interpretation: Land boundaries and land use inside the plots and other land use categories are mapped by farmers. This part involves significant amount of work but is especially important for the farmers. The citizen scientist can incorporate the villagers’ detailed land resource knowledge into the image by plotting the data using mobile devices integrated with web-applications or by using hardcopy images of the area. The later approach was used in this experiment. (see Figure 4)

Figure 4 Detailed image of sloping corn and millet terraces for area and crop harvest calculation

In addition, a test on auto-detecting buildings using machine learning for the entire village was completed successfully using a platform known as Picterra. The ortho-plot mosaic was uploaded to Open Aerial Map and was used in conjunction with Open Street Map to map the village in detail,
something not possible through the OSM default satellite imagery (See Figure 5). In this exercise, the author processed drone images using the open and free software, OpenDroneMap. This open system holds the key to future drone processing when there are limitations for investment in commercial software packages.

**Figure 5 Orthoimage plot mosaic uploaded to Open Street Map**

**BENEFITS OF AERIAL MAPPING FOR INCLUSIVE DEVELOPMENT**

Farmers can easily distinguish many important natural features from drone imagery. A farmer family's resources usually consist one or more of the following:

*Char Ghaderi* – A house and land around the house, animal shed, house yard, and kitchen garden

*Baari* – rainfed terraces; crops are most commonly corn, millet, potatoes. Fodder grass and trees are grown on the side slopes of baari.

*Khet* – mainly irrigated rice fields, double or triple crops can be grown depending on location

*Kharbaari* – land for thatch and fodder grass, often open with few or no trees

*Paakho ban* – groves of trees for building construction, and farm tool making
Orchard – fruit trees grown either on separate land or mixed with other crops

Community land - land with or without patches of sacred forest and grazing land for livestock

Path and trails – Village infrastructure needed to connect households to their fields, to local markets, and to their neighbors

Such detailed land data could be used for planning and decision making at the household level to improve agricultural productivity, by understanding land suitability and carrying capacity, land use planning and land improvement. Aggregated land data in a community provides information on the productive capacity of the area and its potential to support the current and future populations. This provides information to support strategies to reduce out-migration, alleviate poverty, increase equity of land distribution, improve disaster recovery and socio-economic development.

Mapping using consumer drones is inexpensive. Therefore, it can be undertaken repeatedly at different times of the year to provide additional information on seasonal cropping and productivity. (see Figure 6)

**Figure 6 Vertical images taken on two dates (December 25, 2018 and October 26, 2019)**

**SUMMARY: GEOSPATIAL INFORMATION EMPOWERS FARMERS**

Participating in generating information that helps them in their day-to-day life’s decisions empowers farmers right from the beginning. It can equip them with information and knowledge products that support their actions, and trains them in using information in more strategic ways – such as
approaching local government for agricultural inputs and extension services, understanding discrepancies in area and amount of tax paid; or collaborating with neighboring farmers in consolidating land for productive use.

**Policy analysis and learning:** This involves mechanisms for linking the farmers’ data with government’s policies for poverty alleviation, income generation, carrying capacity and suitability analysis; examples include land use planning, consolidation of lands for increasing productivity; making farmer’s data the basis for local government to approve grants and extension services; and establishing land data at the community level. Lessons learned can be used to show how the data can be used in support of local government planning functions by using the village maps to guide questions on how land data can be utilized as a tool to reduce social inequity,\(^{13}\) generate employment - especially for the youth - and target poverty reduction programs. Knowing the exact amount of land for each farmer can foster a community-level understanding of what needs to be done for sustainable land management.

**Institutional mechanism:** Participatory aerial mapping can be done village by village, but in order to ensure optimal value is generated from the data, the work needs to be done in collaboration with the local municipal government. This requires an institutional mechanism to bring landholders and tenants together to engage in mapping and analysis. Marginalized communities can use the mapped evidence to substantiate their requests to local government for help in improving their conditions, particularly by adjudicating their rights of access to resources. Starting with communities amenable to the process and scaling up slowly would give continuity to the process and facilitate expansion using villagers as peer guides and advocates.\(^{14}\)

**Other areas of land data application**

**Land fragmentation** is a recognized issue. It has caused under-utilization of land, emigration, and poverty. Consolidating land for improved production, engaging youths locally in agricultural activities, and linking farm production with markets are important aspects of local economic development.\(^{15}\)

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Land use policy The government issued a land policy in 2019, but it has not been implemented. It envisions proper utilization of land, including imposing certain land use restrictions according to location, preventing conversion of land from productive to unproductive use, etc. Individual farmers’ land data could be used as the basis for local land use and land rights regulations that empower communities in an equitable and just manner.

Budget and resource allocation for the territories within local government units are partly based on the size and productivity of land and the local population. As municipalities build their information base on the actual amount of agricultural land, its productivity potential, and the real population engaged on farms, they should be able to improve their budget allocations for economic support and development. Building a continually expanding land information base would help immensely in building evidence into policy making process at many levels. One specific task that is presently not properly conducted is the estimation of farmer’s input needs for planting—such as fertilizer—and calculations of storage needs at harvest.

Land suitability analysis supports farmers in adopting modern agricultural practices by shifting from traditional less-productive farming to more economically profitable options.

Carrying capacity in terms of agricultural production and population in an area that relies on the production is an important metric for developing a vision for future municipal development.

Local government development management requires a sound information base for planning and executing development work at the municipal and village levels. Taking village aerial mapping to scale would provide a solid basis for building code implementation, address development, and utility access improvement. It can also benefit social programs, such as monitoring implementation of building codes, solid waste management and other environmental programs.

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Indra Sharan KC has worked with geospatial data systems since 1984 when he helped to establish digital remote sensing analytics in Nepal. Later, he created the first digital geographic information system (GIS) for the National Planning Commission and managed it from 1992-1997. He went on to serve from 2002-2019 as the Senior GIS Advisor and GIS Analyst for USAID in Kathmandu, the first mission to completely internalize GIS analysis into its program cycle.