The Usage of Unmanned Aerial Vehicle Technology in Participatory Land Use Planning and Mapping

Sustainable cropland and forest management in priority agro-ecosystems of Myanmar

Project Symbol: GCP/MYA/017/GFF
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Abstract

Participatory Land Use Planning (PLUP) requires active involvement of the local stakeholders and the village tract communities. The use of unmanned aerial vehicles (UAV) in mapping and planning land uses, is an emerging and efficient technology for acquiring thematic spatial data for participatory land use planning and mapping at village or township levels. The use of UAV was preferred for cost-effectively collecting quality geospatial data and information at very high resolution in a flexible, participatory, and transparent manner in NyaungU and Kyaukpaduang townships at Village tract level. Data collected using the UAV included; aerial imagery for mapping of village boundaries, land use, land cover, infrastructure, public facilities and utilities, point cloud data for creating digital terrain models. The same participatory procedures were used in the great delta of Ayeyarwady Region in Labutta Township and in the upland areas of Mindat and Kanteplet Townships in Chin State. The usage of UAV technology enhanced the participatory process by enabling identification of visible land use types, crop types, infrastructure, facilities, and delineable boundaries by the local non-technical village participants. These information was used in the PLUP process at several stages namely; the preparation stage, Mapping existing land uses and other features (infrastructure, utilities, and facilities, delineating village boundary), Mapping of proposed land use sites, i.e. community forest sites, and delineating land tenure systems in the selected project sites.

Keywords: UAV, Participatory Land Use Planning and Mapping
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Acronyms

CF       Community Forestry
CSO      Civil Society Organization
DALMS    Department of Agriculture Land Management and Statistics
DSM      Digital Surface Model
DTM      Digital Terrain Model
FAO      Food and Agriculture Organization of the United Nations
FD       Forest Department
GAD      General Administration Department
GCP      Geodetic Control Points
GNDVI    Green Normalized Difference Vegetation Index
IDP      Internally Displaced Person
LIS      Land Information System
LSC      Local Stakeholders Committee
LUC      Land Use Certificate
LULC     Land Use and Land Cover
LUT      Land Use Type
MIMU     Myanmar Information Management Unit (www.themimu.info)
NDVI     Normalized Difference Vegetation Index
NLIS     National Strategy for Land Information System Development
NLUP     National Land Use Policy
NSDI     National Spatial Data Infrastructure
PLUP     Participatory Land Use Planning
UAV      Unmanned aerial vehicles
VARI     Visible Atmospherically Resistant Index
VC       Village Committee
VFV      Virgin, Fallow, and Vacant
VTC      Village Tract
1. Introduction

The approaches of participatory mapping and planning provide a platform for documenting spatial understanding of local communities by conjoining modern cartography tools, active participation, and interactive mapping planning techniques (Rainforest Foundation UK, 2019). This approach was used to bring forth local historical and indigenous knowledge, social and cultural attachments of the communities on land use, demographic and socio-economic patterns, and other livelihood characteristics at the village level. Participatory mapping was used to enhance PLUP by improving acceptance and ownership of the maps and interactive identification of traditional and indigenous land resources which the communities view as a stratagem for recognition, upholding of land rights, boundaries, and tenure security (IFAD, 2009).

Remote sensing approaches to natural resources mapping have been applied in data collection and analysis for planning and management since 1970s. There are conventional satellite datasets developed, which include Landsat, ASTER, SPOT, ALOS, Rapid-Eye, Geo-Eye, Pleiades, Quick-bird, and IKONOS, Worldview, and Sentinel-2 imagery. These satellite data is mostly used for the exploration of natural resource through remote sensing technologies. However, these data is limited due to cloud cover, spatial and temporal resolutions, and operation costs. Currently, the UAV or drones are used to dynamically capture very high-resolution data; providing a new frontier for collecting detailed spatial data and information on natural resources. Several studies have been conducted using UAV with different spatial resolution fitting specific uses (Kachamba D. et al., 2016, Anggoro A. et al., 2018, Waite C. et al., 2019).

The advent of the UAV applications in remote sensing is increasingly closing the gap between the labor intensive and time consuming ground data collection and the inflexible and costly satellite/airborne observations. In view of the cost-effectiveness, flexibility, and prompt data acquisition, the UAV system has been applied in many areas to generate high resolution ortho-images, point clouds data, and digital surface models (Colomina and Molina, 2014, Crommelinck S. et al. 2019). Maurice et al., 2015 pointed out that the UAV are used in data collection for land administration and updating cadastral maps (Manyoky et al., 2011; Koeva et al., 2016; Jazeera et al., 2014). In addition, the UAV’s high-resolution ortho-photos are used to digitize boundaries of land use or parcels; manually and or automatically and attributive information is added to the generated spatial data (IAAO, 2015). The resulting informative map is crucial for a land use planning, recording of existing land use, tenure systems, and land rights. This consents the establishment of administrative functions, participatory land use planning, and mapping to facilitate decision-making (Williamson et al., 2010). There are other studies using this remote sensing technology to gather spatial information at large scales for environmental monitoring and planning (Nurdin N. et al., 2014, Nurdin N. et al., 2015, Siregar V. P. et al., 2013).

Due to huge costs involved in the collection of land information, the land rights of over 70 percent of the population are unrecognized. This challenge can be resolved using innovative, reliable, affordable, transparent, scalable, and participatory tools purposely for flexible and responsible land mapping and management (Enemark et al., 2014). This can be achieved by simplifying the mapping protocols to allow for participatory marking of boundaries and other features of interest on the ortho-photos. In the event of modification and formalization of the mapping protocols, surveying costs and processing time will be
reduced, while improving efficiency, achieving ownership by local communities and high accuracy (Luo et al., 2017).

Manual and automatic approaches are available for extracting visible feature boundaries from UAV data. The main use of UAV technology in the project areas was to facilitate participatory land use planning and mapping as an alternative for bridging the gap for the required spatial data acquisition that is less costly and more flexible, efficient, and effective at the village tract level.

1.1 Spatial Data Infrastructure (SDI) for Myanmar

The spatial data infrastructure of Myanmar is well defined among several actors. However, there is no clearing house for all spatial data. Data is managed by several institutions within government and non-governmental organizations with each managing spatial data themes under their respective mandates. There are GIS units in the Department of Agriculture Land Management and Statistics (DALMS), the Department of Forestry (DF), and MoIP all managing thematic data. Following the need to harmonize Geospatial Technology in support of SDI, Myanmar formulated the One Map Policy. One Map project has since developed a geoportal for archiving, sharing, and managing all spatial data. Further, a multi-agency team including NGOs and the UN agencies implementing projects within the country, have developed Myanmar Information Management Unit (MIMU) to support the development of NSDI. It is worth noting that the NSDI is still in its infancy as most institutions are still struggling with duplication of efforts and inadequate data sharing arrangement. Considering the emerging demand for UAV technology in mapping and planning, these key players need to formulate relevant policies to govern its utilization.

Figure 1 illustrates the governance structure of Myanmar which also infers the geospatial data administration and management. At national level, data is managed at the Union Territory of Nay Pyi Taw, then each of the 7 regions and 7 states generate and manage their own data. This also is done at the township levels within the respective Ministries and their departments.

![Figure 1. Myanmar Spatial Data and Information Management Structure](Data Source: Design Printing Services (www.dpsmap.com/gis))

For more information, please see Myanmar Information Management Unit (MIMU) website, and insert the link in the acronym.
1.1.1 Regulations governing drone mapping in Myanmar

There is no specific laws governing the drone use. However, the applicable Myanmar laws and regulations for Drone technology usage are drawn from the general principles of safety, security, and privacy. The practice of using drone for mapping is allowed in Myanmar, but when flying the following rules must be followed.

a) Obtain permission to own and operate a drone
b) Avoid flying over large crowds of people
c) Strictly observe and respect the privacy interests/rights of others when flying a drone
d) Avoid flying in proximity to airports (5Kms)
e) Must fly during the daytime and in manageable weather conditions
f) Must not fly over sensitive government areas including military facilities.
g) Avoid flying drones near religious sites
h) Avoid flying drones in Naypyidaw

The permits to operate the drones in Myanmar are issued by the Ministry of Transport and Communication. It is worth noting that there significant restriction for foreign operators due to security reasons.

1.2 Problem statement

The UAV were introduced for military purposes in the in 19’s century. In the recent past, the use of the UAV increasingly extended into applications in civil mapping and planning activities including land cadastral registration, delineating land uses, and village boundaries. Ramadhani (2016) used UAV delineate rice fields boundaries of in Tenggara, Indonesia. Silalahi et al., (2016) who also used UAV for mapping the district boundaries in Indonesia, reiterate this fact. Further, Sadikin et al., (2014) concludes that UAV are applied satisfactorily to resolve geometric accuracy issues, as an approach to rural land parcels mapping and identification of assets, tenure system boundaries. The countries that have used UAV for cadastral include Netherlands; juridical verification of cadastral border (Rijsdijk et al., 2013), Alaska State and Poland; updating cadastre maps, and for taxation purposes (Cunningham et al., 2015, Lukitasari F., 2017).

Participatory land use planning can be ineffective, time consuming and expensive process without current visual data as orthophoto and or maps at sufficient spatial resolution for village/village tract level planning. In the PLUP process the local communities respond well to visible information as opposed to interpreted lower resolution data. Therefore, this project adopted UAV to support the land use planning and mapping at village tract level, and this paper focuses on documenting best practices and lessons learnt in comparison with other terrestrial airborne methods, considering accuracy, cost, time and participatory opportunities. It was noted that most existing village tract boundaries need verification and most village boundaries are not formal.

1.3 Adoption of UAV mapping in PLUP in Myanmar

Participatory mapping for land use planning at village tract level was carried out in the Central Dry Zone, Mandalay Region, Nyaung-U Township (Dahatsee village tract), and Kyaukpadaung Township (Thanbo village tract). In the great Ayeyarwady delta Region; Labutta Township (Baing Daing Chaung village tract) and in the upland areas of Chin State, Mindat Townships (Khee Rein village tract), and Kanpetlet Townships at village tract, were selected for the PLUP process. The mapping of land use types, natural resources, and boundaries was illustrated in a participatory process involving the local communities. Geo-spatial data collected using the UAV included basic geo-information imagery for mapping and documenting land use,
hypsography, inland waters (estuary/brackish), topographical names, boundaries, transportation and utilities, settlements and public facilities. This data was used to gain understanding of the village/village tract level land resources for the planning purposes. The participatory process using the UAV was focused on mobilizing the village community to get involved in the land use decision making within their locality through the gained understanding of the maps developed. The final production of land use maps showing the village boundaries, land resources, land use types, and proposed plans for community forest sites was intended to support efficient and effective decision-making processes. This project aims to develop a model process for PLUP with the aid of UAV at village tract level for replication in other villages within the townships.

1.3.1 Comparison of current satellite and UAV imagery data for mapping at village tract level

Drones are used to autonomously acquire very high resolution imagery, very cheaply when comparing with other sources of similar resolution data including satellite or aircraft aerial imagery (Kakaes, K. et al., 2015). The drone technology is advancing rapidly to levels becoming indispensable in township and community mapping and planning (Nicolás V. and Jaime P., 2019). The demand for the technology has seen pronounced diversification and miniaturization of in-built cameras and sensors in addition to GPSs, navigation systems, radar, multispectral, LiDAR), and temperature sensors; customizing drones for local and village level mapping among other applications (Arfaoui, A. 2017). The freely available and current satellite imagery cannot match the suitability of the UAV data for village/village tract level mapping and planning. Table 1 shows some of the most common and currently available satellite imagery for comparison with UAV data.

Table 1: Comparison of current satellite and UAV imagery data for mapping at Village Tract Level

<table>
<thead>
<tr>
<th>Satellite Data</th>
<th>Resolution (m)</th>
<th>costs</th>
<th>Suitability for mapping at Village tract level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat 8</td>
<td>30m except for the panchromatic band (15m)</td>
<td>Free</td>
<td>Not suitable due to resolution and cloud cover. No Flexible Acquisition</td>
</tr>
<tr>
<td>Sentinel 2</td>
<td>10m for red, green, blue and near-infrared bands</td>
<td>Free</td>
<td>Resolution not suitable enough for village level participatory mapping</td>
</tr>
<tr>
<td>MODIS</td>
<td>250m/Daily</td>
<td>Free</td>
<td>The spatial resolution is too low</td>
</tr>
<tr>
<td>GEOS-R and NOAA-20</td>
<td>250m and above/15min</td>
<td>Free</td>
<td>The spatial resolution is too low</td>
</tr>
<tr>
<td>UAV-MAVIC2 PRO</td>
<td>0.045m/flexible flights</td>
<td>Free(with cost of drone)</td>
<td>Very Suitable for Village tract mapping and land use planning</td>
</tr>
</tbody>
</table>

1.4. Objectives of using UAV in PLUP process at village tracts

The objective of using UAV in PLUP in the place of terrestrial and other airborne methods for mapping land uses include,

a) To take advantage of the very high resolution UAV imagery in facilitating village level mapping
b) To flexibly fly over the regions of interest within the village at will
c) To enhance participation of the local village members in the mapping utilizing current visible features on the UAV imagery
d) To make use of less time consuming, inexpensive drone technology for generating current geo-information at village level.
e) To flexibly delineate tenure systems in selected project sites
1.5 Project Areas

The project areas selected for PLUP represent three different ecological states: the upland areas, coastal zone, and central dry zone. These sites are representative of the general landscape of Myanmar.

1.5.1 Mindat and Kanpetlet townships in the upland areas of Myanmar

Kanpetlet project site is located within 93°29’00”- 94°07’30” E and 20°38’20” - 21°18’20” N while Mindat project area falls within 93°28’30” - 94°07’37” E and 21°04’40” - 21°48’53” N, in Chin State. The Townships lie within the mountainous areas with altitude up to 1463 meters in the southwest of Myanmar. There is a total population of about 64 000 people drawn from multi-ethnic groups with about 50 000 living in the rural areas where they practice shifting cultivation. The townships cover an area of approximately 570 000 hectares. The total protected forest area Mindat is 55 000 hectares and 12 000 hectares in Kanpetlet totaling to approximately 72 000 hectares. Owing to the upland geography of the townships, there is high levels of endemism. However, land degradation is advancing at unprecedented rate due to inadequate land use planning.

Figure 2. Project area I, Kanpatlet Township in Chin State, the Uplands of Myanmar

Adapted from MIMU GIS resources (http://themimu.info/gis-resources) including State and Region Boundary, Township Boundary, Town Locations, Village Locations, Road, River and Hill shade produce from SRTM30.
1.5.2 Labutta township in the coastal zone

Labutta Township is located within 94°32’15” - 95°07’04” E and 15°42’06” - 16°23’43” N in Myanmar’s coastal zone, within the great Ayeyarwady Delta. The Township presents opportunities for integrated crop farming, fisheries, and forestry practices within the coastal zone including exploration of blue economy opportunities. The low lying, moist areas of Labutta Township have substantial mangrove forest and are important for rice and fishery/aquaculture production in Myanmar. The township has total population of 500,000 of which 469,000 people in rural areas and are vulnerable to the Nargis Cyclone. The communities mainly practice non-mechanized, low input rice production in approximately 148,300 hectares, while 73,000 ha are covered by mangrove forests out of the total land area about 300,000 hectares. According to the national plans, Reserved Forests cover about 100,000 hectares.
Figure 4. Project area III, Labutta Township in the Great Ayeyarwady Delta region within the Coastal Zone of Myanmar

1.5.3 Kyaukpadaung and Nyaung Oo townships, in the central dry zone

Nyaung Oo Township is located within 94°49'27" - 95°14'10" E and 20°51'40" - 21°18'16" N while Kyaukpadaung Township falls within 94°59'32" - 95°32'40" E and 20°32'30" - 21°06'50" N, in the Mandalay Region within the central dry zone of Myanmar. The two townships covering an area of about 400 000 ha, have 120 000 ha of forest and 200 000 ha in agricultural use while 80 000 ha are considered a waste land. A single household in the central dry zone, requires 3-4 ha for sustenance. However, 25 percent of the rural populations are landless while most of the remaining population have less than 2 ha. In this zone, Agriculture is the economic main stay, where the pulse crops account for 70 percent of dryland agriculture in addition to paddy, sesame, and groundnut with significant grazing. Further, the residents largely depend on natural forest for livestock production and fuel wood. The area is characterized with ephemeral streams, pronounced water scarcity, and about 20 percent of households falling into the food insecurity brackets.
Figure 5 Project area IV, Kyaukpadaung township in Mandalay region within the central dry zone of Myanmar

Figure 6. Project area IV, Nyaung Oo township in Mandalay region within the central dry zone of Myanmar

Adapted from MIMU GIS resources (http://themimu.info/gis-resources) including State and Region Boundary, Township Boundary, Town Locations, Village Locations, Road, River and Hill shade produce from SRTM30.
2. Methodology for PLUP with UAV

There are three main stages used in the participatory mapping using the UAV: the preparation stage, data acquisition stage, and the participatory mapping stage as illustrated in figure 1 below.

Figure 7. Workflow of PLUP using UAV

2.1 Software and material

There are a number of software available for drone data processing which can be classified open source, free or commercial categories. The free and open source software OpenDroneMap (ODM) and Menci APS were selected for data processing in addition to the Pix4D software; commercially available at reasonable periodic subscription fee. There other available commercial software are shown in table 2.

Table 2: List of free and commercial software for drone data processing

<table>
<thead>
<tr>
<th>Software</th>
<th>Commercial / free/open source</th>
<th>Main products</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>b) Geo-referenced Point Clouds data,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Geo-referenced Digital Terrain/Surface Models</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>d) 3D Models: Textured 3D models in .OBJ format.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>e) Measurements of volume and areas</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>f) Vegetation indexes for checking plant health including NDVI, GNDVI, VARI,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>g) Creates additional GCPs and uses them for improved accuracy.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>h) Produces contours in preview and Contours; Preview and file formats for</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>i) Processed multi-spectral images.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>j) 3D models and easy sharing of data</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) 4 channel imagery</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Photo-Scan Import tool</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>d) Algorithm for DSM generation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>e) Algorithm for filling holes in DSM</td>
<td></td>
</tr>
</tbody>
</table>
The DJI Mavic 2 pro drone having a flight range of less than 10km, a weight less than 5kg, and a flight altitude of less than 250m is classified as a micro UAV. Among its peers which include the DJI Phantom 4 Pro+ (flight time 15min and range 150m), DJI Mavic Air (flight time 20min and range 4 000m), AR X-Star Premium (flight time 25min and range 2 000m), GoPro Karma (flight time 20min and range 2 000m); the DJI Mavic 2 pro has a flight time of 27min and a range of 7 000m. The DJI Mavic 2 pro was selected for the tasks of this project.

To following resources were availed for this project activity;

a) UAV: DJI Mavic 2 pro
b) Instruments: Smartphone; Laptop/ Computer Desktop
c) Software: DJI GS Pro; ODM, Pix4Dmapper; QGIS 3.10.3
d) Personnel: GIS expert, Facilitators, LCS officers (government authorities)
e) Ancillary data: existing geospatial data collected from various providers, including land cover maps developed for township levels

2.2 Data collection

There two types of datasets that were collected; the primary data and ancillary (secondary) data. While the primary dataset was collected through the fieldwork, the ancillary data was obtained from existing records and databases in the respective mandated institutions. The digital imagery was acquired by flying the UAV (DJI Mavic 2 pro) in the project areas of interest. The other tools used for processing data include a laptop computer with QGIS software.
### Table 3. Specification of UAV DJI Mavic 2 Pro

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAV DJI Mavic 2 Pro Weight</td>
<td>907 g</td>
</tr>
<tr>
<td>Max. Speed</td>
<td>72 kph (S-mode)</td>
</tr>
<tr>
<td>Max. Service Ceiling Above Sea Level</td>
<td>7,000 m (Default altitude limit: 120 m above take-off point)</td>
</tr>
<tr>
<td>Max Flight Time (no wind)</td>
<td>31 minutes (at a consistent 25 kph)</td>
</tr>
<tr>
<td>GPS Mode</td>
<td>GPS+GLONASS</td>
</tr>
<tr>
<td>Sensor</td>
<td>1” CMOS Effective Pixels: 20 million</td>
</tr>
<tr>
<td>Lens</td>
<td>FOV: about 77°</td>
</tr>
<tr>
<td>Image Max. Size (width x height)</td>
<td>5472×3648</td>
</tr>
<tr>
<td>Supported File Formats</td>
<td>Photo: JPEG, DNG; Video: MP4, MOV</td>
</tr>
<tr>
<td>Internal Storage</td>
<td>8 GB</td>
</tr>
<tr>
<td>Sensing System</td>
<td>Omnidirectional Obstacle Sensing (left/right, up/down, and forward/backward obstacle sensing)</td>
</tr>
</tbody>
</table>

Data quality and safety of the flight largely depends on the flight paths design. The design of the flyways took into consideration the drone tool specifications, the target feature, and the characteristics of the region of interest. Pix4D software was used to design the flight path based on accessibility and elevation by providing desired flight height, speed, and data capture overlap between flight paths as shown in Figure 8. The village tract boundary was uploaded into the Pix4D Software in a KML file format to guide the design of flight paths. The commonly used flight height in the fieldwork was an average of about 200m and an overlap of 65 percent. The average area covered per flight was approximately 200 acres and a maximum of 5 flights per day with 5 drone batteries. It is normal to cover 1,000 acres per day with a total of around 800 images being acquired per day using the Mavic 2 Pro drone. The ortho-photos and panorama drone pictures were used to map facilities, utilities, and other infrastructure within the village/village tract.

**Figure 8. Pix4D Showing the Setting of Flight Path Characteristics**

![Pix4D Flight Path Setting](image)

### 2.3 Image acquisition and processing

Image Acquisition was done within the village tract boundary in accordance to the flight plans. Trial flights were conducted to test the connectivity between the ground station and the UAV. The flight parameters that
include flight height, side and frontal overlaps and data capture extents were set based on the testing results. The UAV produced aerial imagery/photographs at a spatial resolution of about 4.5 cm taken from an average height of about 200m and an overlap of 65 percent. UAV aerial photographs were processed into orthomosaics and digital elevation model using the Menci and ODM software. The resultant imagery was processed using QGIS 3.10.3 software. The data was projected to Universal Transverse Mercator (UTM), zone 46 North (UTM 1984). Finally, the ortho-photo/imagery was used to identify land uses in the village as well as introduce the new technology to government authorities and local committee. Visual interpretation of the ortho-photo was carried out manually through on-screen digitization. In addition, the resultant spatial data was presented using a projector during the village workshop forum. The participatory land use mapping and planning at the village/village tract data were integrated into the township land use land cover and planning map, produced by this project.

Figure 9. Photos of the DJI Mavic 2 Pro and GIS expert launching drone flight in Labutta

2.4 Participatory land use mapping and planning at village/village tract level

The participatory mapping and planning involved the following standard tools, which include;

a) Hands-on mapping,
b) Using Scale maps and images for boundary demarcations
c) GPS data collection for unclear boundaries area
d) Using participatory on screen 3-D models,
e) Participatory Geographic Information Systems (PGIS), and

The hands-on mapping, was used as basic mapping method where community members drew maps based on their memories on the ground and or a piece of paper. The inexpensive mapping technique required no technology and was low-resource-input, mainly for brainstorming in the village meeting forums. This was used to capture past land uses and invincible features and attributes on the maps and imagery. It enabled the village/community members to familiarize with mapping techniques and achieving consensus on the village/ village tract boundary among neighbor villages. Using scale maps and images for participatory mapping involved discussions with the community members who marked boundaries for the village and
land uses on the topographic maps. This was done in the presence of the Local Stakeholder Committee (LSC), Village committee (VC), and other members of the village tracts. In places where the boundary areas were not clear, field verification were carried out.

The on-screen 3-D modelling was used to enhance the visualization of landforms and other land features for the community members to incorporate into their spatial knowledge and combine it with data on land including elevation, scaled maps, and other geo-referenced models to support decision making. Fly through videos and panoramic views captured by the UAV were used to enhance the spatial understanding of the project areas in addition to internet-based mapping using google earth (IFAD, 2009). Participatory GIS was applied to collect, store, retrieve, analyze, and present spatial information and will be practiced more during the implementation of land use plans and when conducting monitoring.

The village committee members mapped and agreed on the village boundary during the participatory workshops. Among the committee members were the village head, the heads of the neighboring villages, and other village representatives who were knowledgeable of village boundaries. Using village map printouts (AO size), the village committee member marked the boundaries and had a consensus on the village extent and land uses. The participatory mapping of village boundary was carried out in the presence of the township government officials (LSCs) and facilitated spatial experts in the PLUP team. Figure 10 below illustrates the Participatory Land Use Mapping and Planning Steps used.

**Figure 10. Participatory land use mapping and planning steps in Khee Rein village, Mindat township**

- Village Members Sketch Mapping on flip charts
- Participatory Village Boundary Mapping
- Participatory land Use Mapping
- Finalized Land Use Mapping in 3D view
When the land uses were agreed among the participants, it was marked digitally on the computer screen or manually on the printouts for digitization. Field verification was also done to ascertain various features, tree species, land use types, and crop varieties.

3. Results and discussion

The UAV ortho-photos generated from the mosaicked photographs, capture highly detailed ground features to levels never witnessed before in the geospatial mapping as shown in figure 11 below, where tree species, crop types, and farm boundaries are prominently visible. It is an extremely affordable mapping technology when considering the resolution and the rate of areal coverages, perfectly fitting mapping and planning at Township and village levels. Adopting the drone technologies in land use planning improves the social inclusion, enhances transparency, and empowers the local communities. Active participation of the local communities using visible features captured by the drone in their own villages, drew most participants into the whole process of land use planning as a result of the sense of achievement and recognition.

Figure 11. Section of Ortho-mosaic imagery extracted from UAV data acquired on 21/10/2019 in Labutta township

The results indicate the advantages of using UAV for participatory mapping and land use planning capitalizing on its interactive nature, flexibility of flying, and cost effectiveness with very high geometric accuracy and resolution that best fits village level mapping. The geospatial data generated complies with the required data standards. In conclusion, that adoption of the UAV for PLUP process enhances the mapping process through reduced costs, increased interactive mapping, higher resolution products, flexibility and replicability of flying over the targets of interest.
Figure 12. Participatory Boundary Delineation

Data Source: Village tract boundary, village facilities and Ortho-mosaic drone imagery produced by SLM project, and Township boundary from MIMU (http://themimu.info/gis-resources), Rapid Eye Imagery from OneMap Myanmar Project

3.1 Final PLUP output

The final maps indicating detailed geospatial information at the village tract level was recorded for next land use planning processes. The main next step is to compile the information collected from the local people and land users with the current LULC, Land suitability and capability analysis results, land tenure, and National Land Use Policy for Myanmar to come up with Draft Township and village tract land use plans. The draft land use plans will provide the local communities with prioritized alternative land use types for selection into the final plan through a participatory process. Figure 12 shows a digitized village boundary and land use features presented in an on-screen 3D model to the villagers for confirmation.

Figure 13. Digitized village boundary and land use features presented in 3D model to the villagers for confirmation

Adapted from OneMap Myanmar Project resources including village tract boundary, village facilities and Ortho-mosaic drone imagery produced by SLM project, and Rapid Eye Imagery.
3.2 Discussion

Several studies approve the usage of UAV in mapping and describe this practice as efficient, effective, accurate, and lower cost compared to the conventional techniques. Ramadhani (2016) carried out participatory mapping of rice field boundaries using UAV for surveying and mapping in Indonesia and concluded that UAV usage in mapping is 70 percent cheaper compared to terrestrial method (Ramadhani, 2016). Further, Radjawali & Pye (2015) conducted a study on the usage of UAV for participatory land mapping West Kalimantan, where the village participants identified their land properties. Sadikin et al., (2014) also used UAV for identifying and inventorying state assets (Sadikin et al., 2014). In view of these studies, it is prudent to apply participatory land use planning using UAV at village tract level.

Nevertheless, the uses of UAV in land surveying and or mapping is mostly restricted to government purposes. There is a need to formulate a flexible policy on the UAV for mapping and strict enough for observing security measures and privacy rights.

3.2.1 Drone technology requirement in township level mapping and planning

The Townships have huge mapping and planning responsibilities and functions that can be economically and efficiently carried out using UAV. The technical capacity required to operate township drone mapping functions are well documented in various literatures and capacity building can be done for the local staff. However, there is a need to carry out needs assessments before deploying drones for mapping as a best practice and limit the social risks associated with the new UAV technology applications. In addition, the needs assessment will help to optimize time, resources, and reduce potential tensions and or conflicts that may include political interests (Paneque-Gálvez, J. et al., 2016). Further, before drone deployment it is important to map key actors, establish the intended drone applications, required trainings, drone and data ownership, data sharing arrangements, and a management plan (Vargas-Ramírez, N. et al., 2018.). Considering the emerging requirements for drone technology at township levels and the diversity of drone purposes, there is need for formulating regulations and guidelines for applications in resource mapping and planning.

3.2.2 Best Practices for drone applications in mapping and planning

a) Preliminary/needs assessments:

This practice should be focused on the following;

(i) Identifying existing/past projects that benefited from or were hindered by drone applications;
(ii) Identifying the key stakeholders or actors that may be in support of or against the application of drones and or the data collected;
(iii) Identify the Government institution mandated to control or enhance the use of drones at the national to local levels or those institutions that manage data collected using the drones
(iv) Identify the conflicting situations that may be escalated or ameliorated in the events of drone applications;
(v) Carry out a needs assessment and the local capacity in terms of literacy and infrastructure i.e. internet, mobile network coverage, ICT equipment, etc.
(vi) The existing rules and regulations including the local and national legislation that may favor and or limit drones applications in various functions.

b) Design of the mapping and planning activity:

The design determined by the following;

(i) The purpose of the UAV data and images;
The mapping extent and terrain characteristics are used to decide on the drone type and size;

(iii) The capacity needs of the community in acquiring, processing and analyzing UAV data and information;

(iv) The requirement for equipment sharing and or data sharing should be drafted into agreements between the key stakeholders

c) Implementation:
The implementation of any project involving drone application within the township or local communities will require the following;

(i) A free explicit consent that is solicited prior to the project commencement;

(ii) The agreed mode/format of delivery and or sharing of information and data resulting from the use of UAV.

(iii) Established data quality framework including control points for geo-referencing;

(iv) Documented needs of the township or community; either financial, Technical, or infrastructural requirements for implementing participatory approaches for data acquisition, processing, and analysis;

(v) The durability of the equipment (Drones) provided including its robustness in terms of repairs and maintenance

d) Monitoring:
There should a monitoring plan determine the following;

(i) Whether the community or township expectations from drone applications are met;

(ii) Whether selected the drone type(s) corresponded with the information and data needs of the townships while meeting the maintenance, repairs, and replacements as per the specifications.

(iii) Check for any additional requirements or improvements required in terms of equipment (improved camera specification for multispectral sensors), applied methods or additional actors required in order to authenticate drone data with the objective of meeting the community interests;

(iv) Check for any changes in information and data needs

(v) Formulate any appropriate corrective measures to address potential factors that can cause deviation from achieving township satisfaction in drone applications

c) Mitigation of negative impacts
In the course of the project implementation, there may rise unachievable expectations which may lead to mistrust if not properly addressed. If there is lack of funds, capacity to manage drone information is inadequate, the project leadership should timely address the issues transparently and decisively. The decision may include project closure and documentation of lessons for future improvements

4. Conclusion

The usage of UAV in PLUP is more interactive and participatory, time and cost efficient, flexible in timing and frequency of flying, provides data in appropriately high resolutions for village level mapping, and is easy to learn and practice by the local technical officers. The UAV/Drone technology provides alternative method of flexibly providing spatial data in very high spatial and temporal resolution for land use mapping at village level with very high accuracies. The main challenge in data acquisition using the UAV is the dynamic fluctuation of the nature of weather and topography. Further, standardization of technical factors affecting data quality including overlap, flight speed, and height is required.

The ortho-photo produced at village level can be used for land use land cover classification by applying segmentation methods. This data can be used to identify tree species, crop varieties, aquaculture, rice fields,
settlements, road networks, house yard, cultural sites, public and social facilities and utilities. The maps showing village boundaries and land resources are a fundamental basis for achieving the objectives of participatory land use planning at the village level. Spatial planning and land use mapping can be used document land suitability and capability based on the historical and indigenous knowledge of the local populations. In UAV methods for participatory land use mapping, a notification letter and holding of LSC pre-meetings are mandatory procedures for presenting task overviews and gain permission to fly before meeting the village level participants.
References


Annex 1

Figure 14. Section of drone panorama photos extracted from UAV data acquired on 24/01/2020 in Mindat Township

Figure 15. Section of Ortho-mosaic imagery extracted from UAV data acquired on 25/02/2020 in Labutta Township

Figure 16. Section of panorama photo extracted from UAV data acquired on 21/10/2019 in Labutta Township
Figure 17. Current Land Use Land Cover (LULC) Map

Adapted from SLM project resources including village Tract Boundary, current land use land cover data and Hill shade from SRTM 30.

Figure 18. Proposed land use plan resulting from the community participation

Adapted from SLM project resources including village Tract Boundary, current land use land cover data, Ortho-mosaic drone imagery and Hill shade from SRTM 30.
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