Identification of Appropriate Drone Technology and its application areas for Agriculture Automation in Bhutan

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Abstract

Various applications of drones in agriculture sector around the world have been analysed in this paper. One of the conclusions after the study conducted indicates that almost all of the tasks are not fully automated but relies on the drone operator. The role played by the operator is varied depending on the type of tasks performed. Nevertheless, irrespective of the level of involvement of the operator, all the agricultural tasks noted in this study benefited immensely by the involvement of drones. The agricultural characteristics and limitations in Bhutanese context were studied along with the drone obligatory restrictions from the Bhutan Civil Aviation Authority (BCAA). The application areas to agricultural sectors in Bhutan which are legally and economically feasible have been mapped. The study also proposes the drones to be owned and operated by local government officials or community centre heads since farmers are not eligible to own the drones as well as due to small land holdings it is also not feasible.

Key words – *Drones, UAVs, Agriculture*.

Introduction

Drones which are sometimes referred as Unmanned Aerial Vehicle (UAV) or Unmanned Aerial System (UAS) are pilotless aerial vehicles consisting of a UAV, a ground-based controller and a communication system between the two. UAV were primarily developed for military purpose to carry out tasks which were deemed too dangerous for humans. With the advancement in technology and cost of production, drones have found use in multiple different sectors from commercial, research to hobbies. The adoption of drone technology for non-military activity was so profound that at present, the number of civilian UAV vastly outnumber military drones.

Agriculture is the science and art of cultivating plants and livestock. Agricultural land in Bhutan was reported at 13.61 % in 2016 including paster land. Almost all aspect of agriculture in Bhutan is human resource intensive but at the same time due to ever-increasing rural urban migration, the villages are facing problems of labour shortage. There has also been an increase in the number of human-wildlife conflict further demotivating the farmers.

The automation during industrial revolution was predominantly focused on mundane repetitive tasks which were very human-resource intensive. The field of AI has seen additive growths with long phases of relatively small breakthroughs followed by sudden field changing breakthroughs. Use of automation in agriculture is relatively new and almost all the tasks are just partially automated. The study carried out focusses on the areas in agriculture that can benefit by the use of drones and study its suitability for adoption in Bhutan.

Methodology

The use of drones has gained popularity with its promising benefits in various sectors of economy of the world, especially the agricultural sector. Some of the research works predict the increase in the demand for drones or UAVs to $4.8billion by 2024. The images captured and information gathered from drones help the farmers in decision making and eventually help improve their productivity, increase their yield, make proper plans of plantings and cautionary activities. A huge amount of time, energy and labour can be saved by using drones in agriculture as the farmers or the drone operators don't have to walk on foot over miles of stretch of fields. Based on the aim and objectives of the study, the methodology as shown in figure 1 was developed and adopted.

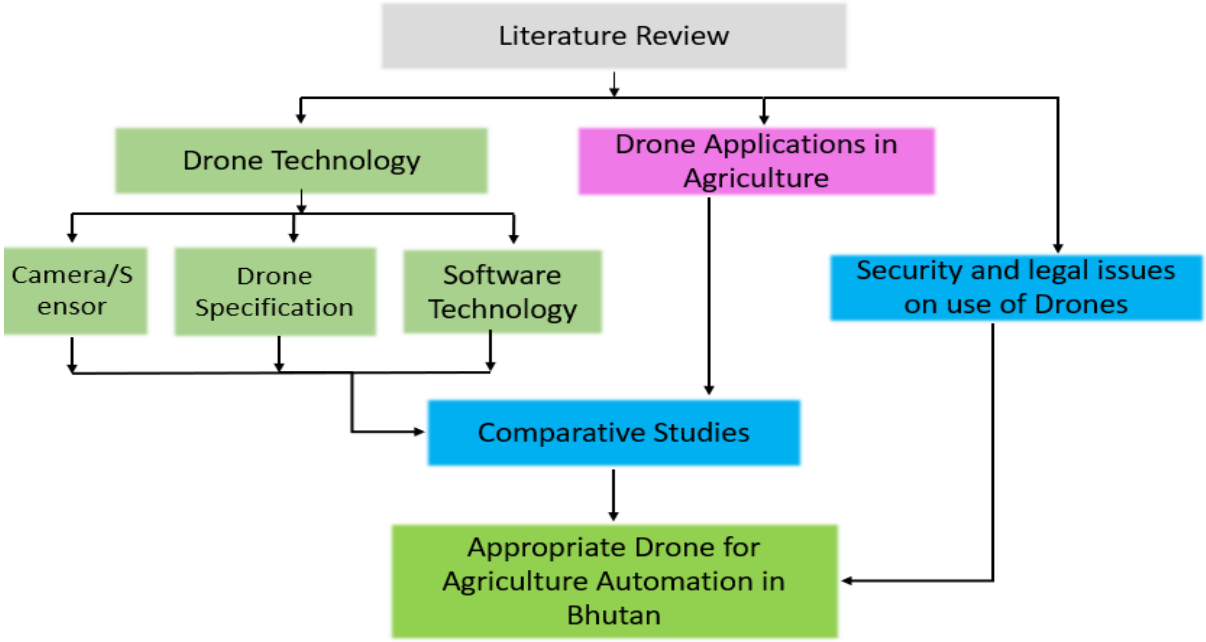
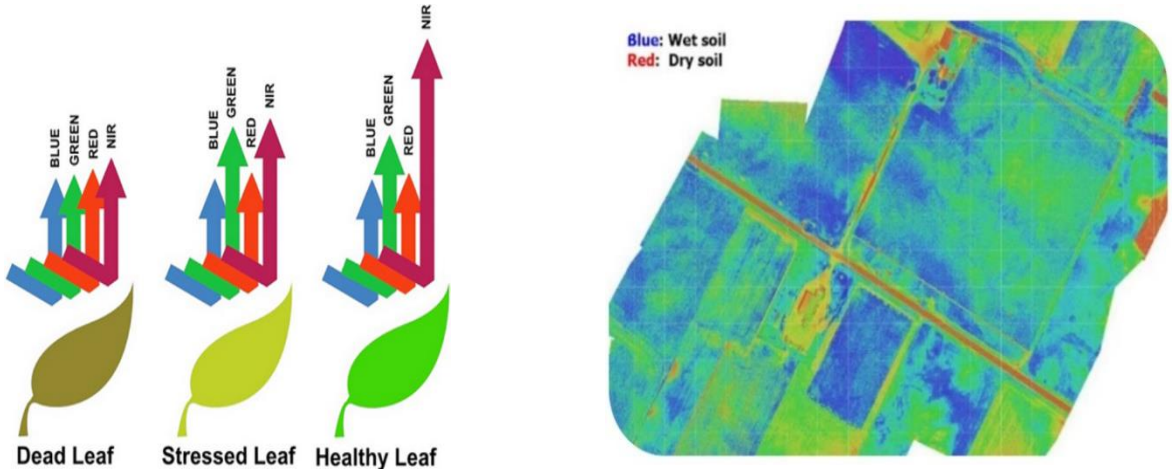


Fig. 1 *Methodology*

DRONE TECHNOLOGY AND ITS APPLICATIONS

Precision farming or agriculture means precise monitoring and managing of crops and soil conditions with the aim to increase productivity and efficiency for different field conditions. This type of farming is also known as site specific farming. It combines new technologies such as GPS (Global Positioning Systems) and GIS (Geographic Information Systems).

Precision agriculture (PA) is a farming management system which is based on observing and then measuring the inter or intra field variability of crops, followed by response actions. With the help of normal cameras mounted on the drones, information on plant growth, coloration, etcetera can be gathered, which all comes under *Crop Monitoring*. PA is one of the most successful applications of drone technology where imaging equipment like normalized difference vegetation index (NDVI) can be used to monitor the health of crops.



(a) (b)

Fig. 2 *(a) Crop Health (Image courtesy: agribotix.com)) (b)Soil condition in field (Image courtesy: croptracker.com*

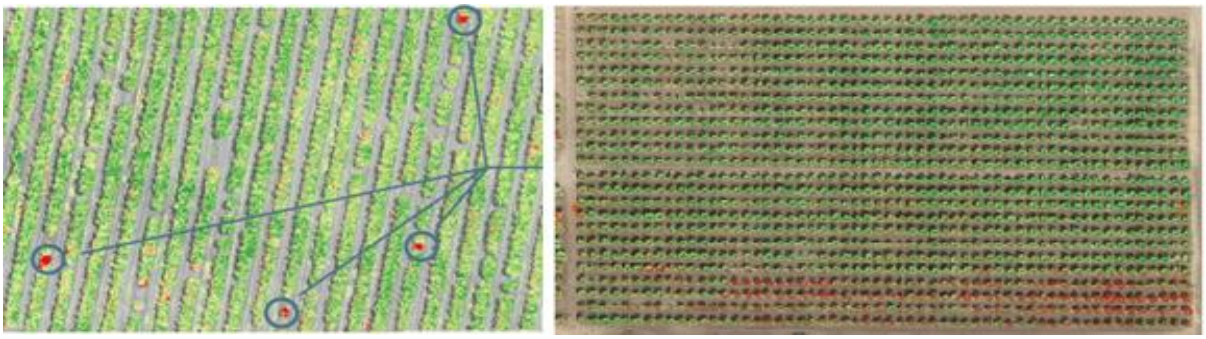
The basic principle of NDVI is to observe the NIR (Near Infrared Imagery) reflected by the crops from the images captured by the drones. Figure 2 (a) shows the typical condition of crops using the NDVI principle. Higher the value of NIR, which is invisible to the naked eye, healthier the crops are. Very low value of NIR could mean dead plants which might need replacement. Satellite images' accuracy can be up to meters, whereas drone images can be accurate to up to few millimeters. Moreover, immediate actions can be taken after identifying the problematic and it is cheaper in comparison to obtaining and analyzing satellite data. The main aim of PA is to ensure profit, efficient and sustainable agriculture.

Drones can be used for *Field Monitoring*; to monitor the field conditions and check the soil health also. With the help of geospatial information from the drone images taken for a particular field, the field mapping can easily be done. The output can provide details like elevation data at different locations of the field and soil moisture condition, enabling the farmers to distinguish wet soils from dry soils. Figure 2 (b) obtained from a drone illustrates the plots of a field with the presence of wet and dry soils.

Quality of soils is very vital in agriculture to any farmer and *Analysis of Field Soil* is a must. Drones can be used to precisely measure and analyses the health of soil. Good or bad quality soils, soils requiring nutrients and soils needing water can be successfully distinguished with the use of UAVs. Accordingly, the type of farming, plantation activities, irrigation system and crop management methods can be adopted depending upon the results of the soil analysis.

Top grade drones or the drones with good quality cameras along with multispectral camera sensors can be used to identify or detect disease or stress at an early stage of plantation. Real time images obtained from the drone surveys can be

analysed for *Crop Health Monitoring (crop scouting)* and early treatment of plants if diseases or any deficiency is detected.



(a) (b)

Fig. 3*(a) Location of citrus trees affected by fungal disease, (b) Detection of low (red ones) chlorophyll in plum tree orchard (Image courtesy: equinoxsdrones.com)*

Damage to crops due to hazards like flood and fires, infestation by pests and etcetera can be assessed with the help of drones with necessary sensors. The data retrieved from the drones along with the application of photogrammetry and remote sensing can be used to prepare orthomosaic files in two or three dimensions for Crop Damage Assessment. Accordingly, the files will be very important and can act as evidence for the farmers in order to claim funding or insurances from the government if the losses are quite huge due to any calamity.

Sky Farming includes planting seeds and spraying by drones. *Planting seeds* with drones is one of the new applications of drones in agriculture and forest industries. It has a huge scope of booming the drone industry in future. Plantation with automated drones will help the farmers sow seeds in difficult areas or high terrains of the farmland. As per the evening standard (London News, 2019), 10 drones have the capability to plant 400,000 trees in a day, operated by just 2 operators.

(a) (b)

Fig. 4*(a) Firing of seed pods by drones (Image courtesy: standard.co.uk) (b) Drone used for Spraying (Image courtesy: croptracker.com)*

Spraying by Drones can be done to spray over locations hard to reach by the farmers and can be navigated through high altitudes. As drones will be spraying pesticides or chemicals to reduce weeds, the back pack load to be carried during

manual spraying will be eliminated, indirectly keeping the workers away from hazardous and toxic chemicals. The affected areas can be identified and sprayed accordingly, saving the chemicals from being spread at random. This activity using drones will save labour, time, cost and even promote an efficient system of soil treatments and maintain good crop health.

Drones have the potential to be used in place of shepherds and cowboys in locating and gathering animals in farms. UAVs embedded with infrared cameras and sirens can be maneuvered around large farmlands to locate and direct the farm animals towards their shelters for feeding, milking and other activities. It can technically be named as ***Aerial Mustering*** where conventional work of farmers and herders are automated, saving the huge amount of money which would otherwise be spent in operating helicopters and experienced pilots.

(a) (b)

Fig. 5*(a) Drone cattle mustering, (b) Traditional aerial mustering using helicopter (Image courtesy: google.com)*

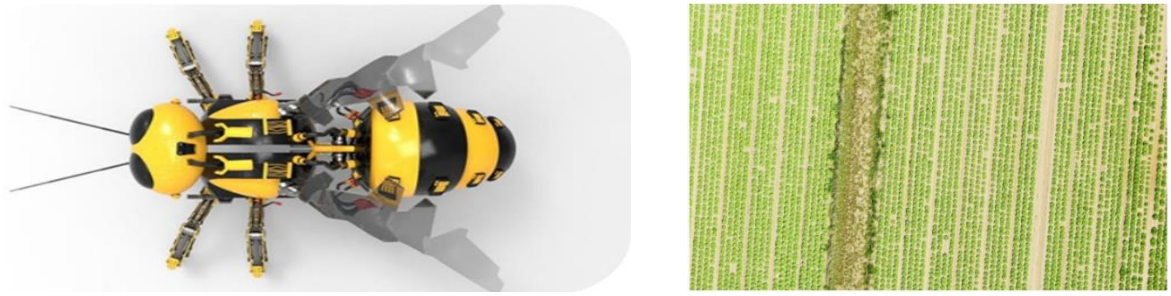
Irrigation Management related issues can easily be solved using drones equipped with thermal imaging or drones with photogrammetry, remote sensing and geo-referencing capabilities. Areas with problems like drought, land with too much or too less water can be presented in the form of RGB images from drones. Accurate topographic maps of the area of interest can be generated and accordingly decisions can be made. Water can be distributed efficiently after analysing the condition of the fields, drainage flows can be managed, water runoff locations and waterlogged areas can be identified and appropriate measures can be incorporated.

(a) (b)

Fig. 6*(a) High quality drone image locating waterways and fields (Image courtesy: qlddrones.com.au) (b) Water sprinkling drone (Image courtesy: google.com)*

Drones can prove to be one of the most useful solutions to the emerging issues to Climate change, wherever there are drought and other related problems with such innovative actions.

Bees or any pollinating insects play a very important role in agriculture. Many crops, fruits and vegetables require pollination to yield properly. Bees also enhance honey production, adding more to economic development. Some countries like the Netherlands and Japan have been conducting research and developing drone pollinators for ***Aerial Pollination*** and to secure crop yields. Micro UAVs (aka robotic pollinators) equipped with cameras, GPS systems and some AI technology can be used for artificial pollination without damaging the crops.



(a) (b)

Fig. 7(a) Drone Pollinator (Image courtesy: croptracker.com) (b) Orthomosaic Image of a Farm (Image courtesy: equinoxsdrones.com)

Field Security and Crop Count while managing farms can be very handy with the help of drones with mounted cameras. The overall view of the farm can be obtained from the drones, the whole area and the borderlines of fences will be easily monitored using security drones. Drones can locate any missing or injured or sick farm animals, and immediate actions can be taken. It not only saves time for the farmers without having to walk acres of field, but also can save lives of the animals and ensure efficient farming practices. Within minutes the farms can be monitored and can be protected from wild animals or any encroacher as well. Drones with high resolution cameras and integrated with algorithms of machine learning, can be used to count the crops or present total farm production. Analysis of maps or 2D orthomosaics can be analysed to predict the yield of farms.

Table 1 *Types of Drones*

Drone/ UAV	UAV type and Cost	Sensors	Area Coverage	Application	Specifications
eBee SQ	Fixed wing, $12000+	Sequoia 5-spectrum sensor (4 spectral bands + visible/RGB)	500 acres in single charge	Vegetation indices, crop count, soil moisture, soil temp, topography, 3D mapping	Weight: 1.1 kg Flight time: 55mins Altitude: 400ft Data resolution: 12cm/pixel
PrecisionHawk Lancaster 5	Fixed wing, $25000+	Multispectral, Lidar, Thermal infrared, Hyperspectral	300 acres per flight	Crop count, crop height, volume measurement, vegetation indices, 3D mapping	Weight: 3.4kg Flight time: 45mins Altitude: 300ft Data resolution: 1cm/pixel
DJI Agras MG-1	Multi rotor, $6000+	Radar sensing, filter and centrifugal cooling system	7-10 acres per hour of operation	Spot spraying of herbicides, pesticides and fertilizers.	Weight: max 24.5kg Flight time: 3.5hours Carrying capacity: 10kgs or 10 litres
DJI Phantom 4 Pro	Multi rotor, $1700+	Visual sensor	100 acres per single charge	Field survey, locate animals, security purpose	Weight: 1.4kg Flight time: 30mins Altitude: 300ft Data resolution: 1cm/pixel
Sentera PHX	Fixed wing, $6000+	Sentera double 4K sensor payload, NDVI, NIR, GPS	700 acres in a single flight	Monitor crop health, weed detection, managing pests, infrastructure location	Weight: 1.8kg Flight time: 60mins Altitude: 400ft Compatible to many sensors/ payloads

Phantom 4 Pro NDVI Upgrade	Multi rotor, $3800+	NDVI single/ multiple sensors, NIR	100 acres per flight	Monitor crop health, crop scouting, security purpose, infrastructure location	Weight: 1.6kg Flight time: 30mins Altitude: 300ft Data resolution: 1cm/pixel

Advantages and disadvantages of drones in agriculture farming

Drones are used to capture images which can be analysed using software to develop reflectance or orthomosaic maps to monitor farms. There are many other applications of drones with a number of advantages. However, like any other technology, various drone applications have a set of advantages and disadvantages. Therefore, any organization or a farmer in specific needs to weigh the pros and cons before adopting any drone application or buying a drone. Table 1 is a list of advantages and disadvantages of drone technology or applications of drones in agriculture.

Table 2 *Advantages and Disadvantages of Drones*

Advantages	Disadvantages
✓ Planting seeds by Drones ✓ Monitoring Moisture ✓ Mapping or Surveying ✓ Spraying fertilizers and pesticides by Drones ✓ Cost effective than satellite data ✓ Infestation Prevention ✓ Analysing Crop Quality ✓ Reduction in Labour or Operational costs ✓ Easy to learn or easy deployment ✓ Time Saver	✓ Drone tackling locust infestation ✓ Limited flight range and flight time/ short lifespan ✓ Expensive Initial cost of purchase ✓ Interference with airspace ✓ Safety Concerns ✓ Connectivity/ internet reliant ✓ Weather dependency/ reliance ✓ Legal registrations ✓ Knowledge and Skills Limitations/ requirement of Timely Training

Agriculture in Bhutan

Agriculture in Bhutan is still the major source of livelihood of the people. Despite just accounting for 17.3% of Gross Domestic Product (GDP) of the country (in 2017), agriculture sector employees around 69% of the population. The low contribution to GDP is due to the prevalence of subsistence farming in the country. Subsistence farming is a type of farming in which the majority of farm yield and livestock products are used to sustain the farmers family with little to no surplus left for sell or trade. The farmers practice mixed farming where they plant multiple crops on their land whereby

increasing the complexity of tending to requirements of multiple crops compared to just one.

The agriculture sector in the country is characterized as labor intensive with relatively low intensity of farm inputs. The issue is aggravated by the increasing rural-urban migration turning many ancestral farm lands fallow. Some of the other issues are presented in Figure 8.

Going by the agricultural land types 21% are irrigated wetland, 43% are rainfed dry land, 27% is used for shifting cultivation, 3% is used for orchids and approximately 1% are kitchen garden.

Although food self-sufficiency has been the goal of the nation since first plan. The percentage amount allocated to the agriculture sector has been shrinking every time since the 4th five-year plan (FYP). 44% of the budget was allocated for agriculture sector which then dropped to 33% in the fifth plan. In the 10th and 11th, the budget was 6% and in the current 12th FYP the ministry had asked for 9 billion ngultrums but was allocated 3 billion. In percentage it was an increase to 8% compared to previous FYP. It has to be updated that due to the Covid-19 situation in the county the budget has been reappropriated to 7 billion. Between 2014 and 2016, Bhutan had 46.7% self-sufficiency in rice, 84 % self-sufficiency in vegetables and 86% self-sufficient in maize. Due to low self-sufficiency, Bhutan imported 90,000 MT of rice in 2017.

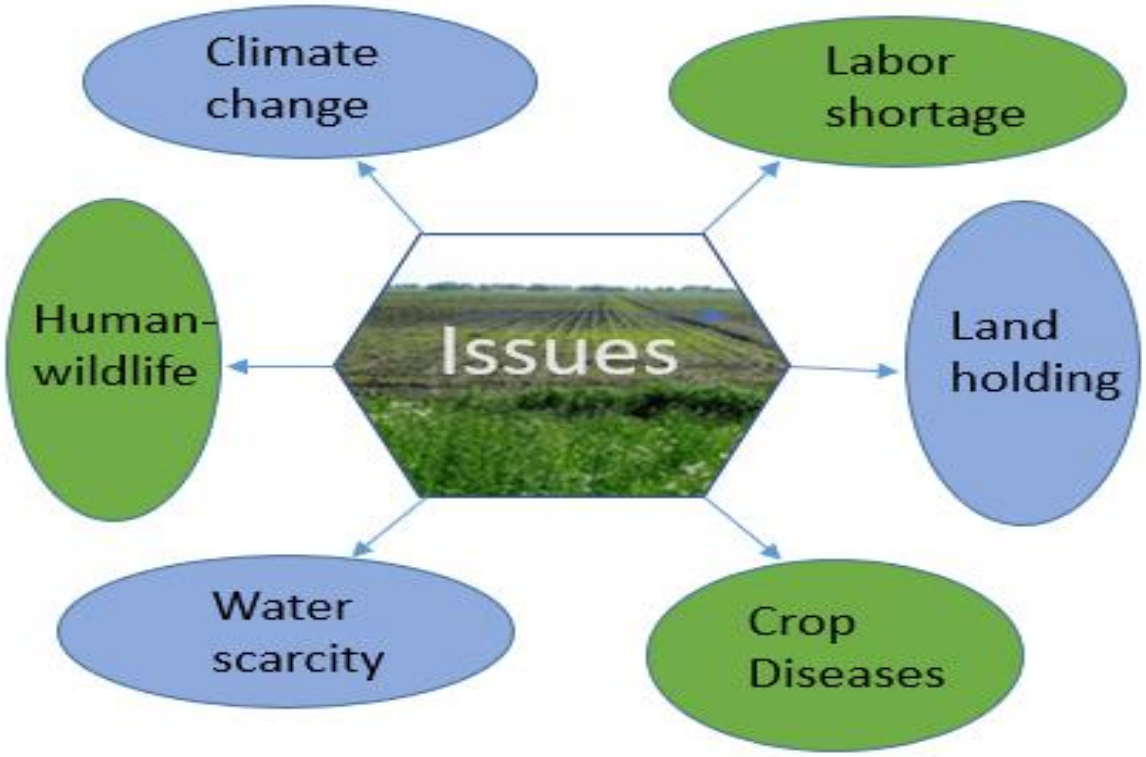


Fig. 8 *Issues in Agriculture*

Drone Regulations in Bhutan

The regulation for drones was published in May-2017 by the Bhutan Civil Aviation Authority (BCAA). The regulations have gone through some modifications with the last amendment done in September 2017. There were no newer amendments after 2017. As a general conscience the regulations are very restrictive in nature. The regulation states that drones with maximum weight of 6.5 kgs are allowed. But the general weight of agriculture specific drones is usually around 24 kg. The regulation does state that the heavier drones will be allowed using special permission. Few other restrictions are as shown in Figure 9.

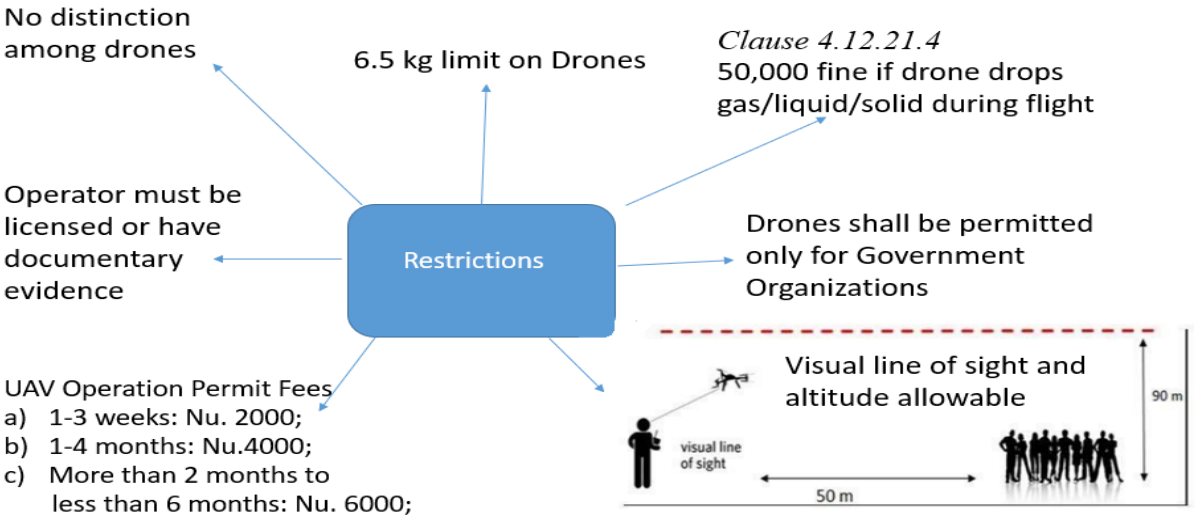


Fig. 9 *Drone regulations in Bhutan*

Conclusion

After thorough literature review and detailed investigation of the applications of drones in agriculture, advantages and disadvantages of drones, types of drones, and most importantly the agriculture in Bhutan, authors conclude that the most useful and relevant drone applications for the country would be Precision Agriculture and Field Security.

Firstly, authors would like to suggest that since farmers are not eligible to own the drones and due to small farm holdings of farmers, therefore local government officials or community centres are recommended to buy the drones and operate it for all the farmers in their locality. These tasks can be performed as a service to the farming community for free or a minimal fee can be charged.

Precision farming, also known as precision agriculture, is a series of processes involving the management of crops and farms in general, integrating information technology (IT) techniques. Precision farming involves:

- ✓ Crop Monitoring
- ✓ Field Monitoring
- ✓ Field Soil Analysis

- ✓ Crop Scouting/ Crop Health Analysis
- ✓ Crop damage assessment

All of these tasks can be performed using specialised drones or by fitting specialised sensors on normal drones. In addition, if a normal drone is used, additional higher-level processing needs to be performed using computer vision tasks. Specialised drones are expensive and would not be economically feasible for small communities in Bhutan. Based on the cost effectiveness, *Phantom 4 Pro NDVI Upgrade* would be the best suited drone for agriculture in Bhutan. It is affordable and monitoring crops with high resolution camera and NDVI sensors will promote efficient and sustainable farming. With the help of cameras and sensors mounted on the drones, the specialized sensors can alert farmers to changes like normalized difference vegetation index (NDVI), leaf area index and photochemical reflectance index. This allows farmers to notice developments the human eye would not. Aerial images can be processed with the help of software like Agisoft. The result can then be used to perform higher level tasks using a custom CNN network. The training images to train the CNN can be procured with the help of domain knowledge expertise of NPPC. If enough samples are not generated then algorithms which depend on small dataset can be used like one shot learning or zero shot learning. The algorithms in conjunction with the drone images will benefit the farmers immensely since crop diseases can be identified or detected an early stage of plantation. Real time images obtained from the drone surveys can be processed and analysed for crop health monitoring and early treatment of plants if diseases or any deficiency is detected. Drone can be used to create multispectral images of the crop based on the camera properties. Infrared images capture details (such as leaf deviation, etc) which is normally not visible through just the visible spectrum images. These images can be analysed to see the health of the plant enabling the farmers to provide timely intervention. Since the list of pests and diseases are already maintained by NPPC we can train a neural network just for those diseases.

Fig. 10 *Phantom 4 Pro NDVI Upgrade (Image courtesy: google.com)*

Drones are cheaper compared to the use of manned aircrafts and use of satellite images for analysing the farm condition. Precision farming eventually helps in efficient and productive farming with timely monitoring and scouting. A lot of time and money will also be saved with this technology integrated farming method.

Field security and managing farms can be very handy with the help of drones with mounted cameras. Although ideally if the farmers are allowed to fly nano drones (weight less than 250g) they will be able to monitor their field for pests and wildlife from the comfort of their house. And using drones they will be able to detect wildlife much earlier than they reach the field due to the bird's eye view of the drone images. Although this task is hampered by the 90 m height limit set by civil aviation, since a normal drone can be flown to a height of 500m. Higher flight would have been able to cover more area and the drone operator would have been able to detect wildlife movements much earlier and warn the villagers. But a set limit of 90m will still benefit. Application of drones for field security will especially benefit in regions where there are frequent encounters with large wildlife which threatens the lives of villagers and their livestock like elephants or bears. Another application in field security is that the drones can be used to search for lost livestock. The overall view of the farm can be obtained from the drones, the whole area and the borderlines of fences will be easily monitored using security drones. Drones can locate any missing or injured farm animals, and immediate actions can be taken. It not only saves time for the farmers without having to walk acres of field, but also can save lives of the animals and ensure efficient farming practices. Within minutes the farms can be monitored and can be protected from wild animals or any encroacher as well. For this task no specialised drones are required and these tasks can be performed using a normal visible spectrum camera mounted on the drone.

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