The photo is from the Official Facebook page of Desuung (Guardians of Peace) taken during the launch of the million fruit trees plantation and geocoding that followed after a year. (Desuung Facebook Page)

Geocoding of Million Fruit Trees for Monitoring and Tracking (Bhutan)

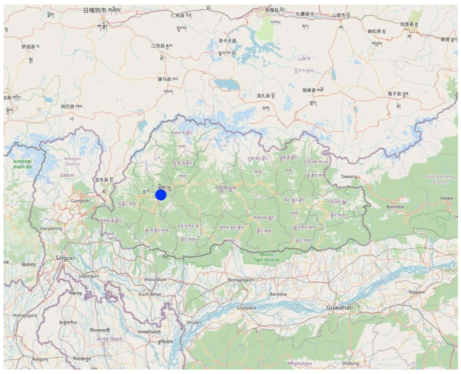
Shingdrey Changm Saya Zukchong Tatok Gi Dhoen lu Sa Chhai Dhadhoen Dhulen (ཤིང་འབྲས་ལྷུངམ་ས་ཡ་འཛུགས་སྐྱོང་བལྟ་རྟོག་གི་དོན་ལུ་ས་ཆའི་བརྡ་དོན་བསྡུ་ལེན།)

DESCRIPTION

Geocoding of fruit trees allows remote monitoring and progress tracking of the growth of seedlings. The Smart App MoDA (Mobile Operation and Data Acquisition) is used in geocoding.

Geocoding of the "million fruit trees" initiative has been carried out across Bhutan. Different fruit trees suitable for particular agroecological zones were planted in farmers' fields in twenty districts and each sapling was geocoded.
The main elements of geocoding fruit trees involve assigning unique geographical codes or coordinates to individual trees within an orchard, utilizing technical specifications and equipment such as handheld GPS to accurately determine the location. The potential benefits of this form of geocoding include:
1. Location Mapping: Geocoding allows fruit trees to be accurately located on a map, providing a visual representation of their spatial distribution. This mapping can help identify patterns, clusters, and gaps in tree distribution.
2. Data Integration: Geocoded data can be integrated with geographic information systems (GIS) and other data sources, such as climate data, soil information, and topography. This integration provides a holistic view of the factors influencing fruit tree growth and productivity.
3. Precision: Geocoding provides precise coordinates for each fruit tree, enhancing the accuracy of data collection and analysis. This precision is crucial for making informed decisions regarding tree management and resource allocation.
4. Monitoring and Management: Geocoded fruit tree data enables efficient monitoring of tree health, growth, and potential issues. It facilitates targeted interventions, such as irrigation, fertilization, and pest control, based on the specific needs of individual trees or clusters.
5. Yield Estimation: By combining geocoded data with relevant environmental and growth information, it's possible to estimate the potential fruit yield in specific areas. This information aids in resource planning and harvest predictions.
6. Disease and Pest Management: Geocoded data can help identify patterns of disease or pest infestations. Early detection through geocoded monitoring can enable prompt intervention and prevent the spread of pests or diseases.
7. Biodiversity Analysis: Geocoding allows researchers to study the diversity of fruit tree species in different regions. This analysis can be useful for conservation efforts and understanding the ecological impact of specific tree species.
8. Research and Analysis: Geocoded fruit tree data serves as a valuable resource for scientific research. Researchers can study the effects of climate change, urbanization, and land use changes on fruit tree populations and ecosystems.
9. Decision-Making: Geocoded data assists farmers, agricultural agencies, and policymakers in making informed decisions about land use, tree planting initiatives, and resource allocation for sustainable agriculture.
10. Community Engagement: Geocoded maps of fruit trees can be shared with communities, promoting awareness of local resources, fostering community engagement, and encouraging initiatives like urban orchards or community gardens.
11. Data Visualization: Geocoded data can be visualized using maps and spatial tools, making it easier to interpret and communicate information to various stakeholders.
12. Long-Term Tracking: Geocoded data allows for long-term tracking of changes in fruit tree populations, aiding in the assessment of the success of planting initiatives and the overall health of the environment.
The major activity of the technology is marking the fruit trees with the help of GPS so that these geocoordinates can be useful in tracking down the exact location of the plant. Geocoding is labour-intensive as the field workers need to be physically present in the field while carrying out the activity. Then the data recorded in GPS is transferred to the computer and analyzed using ArcGIS. This information is available to the policymakers and Agriculture

LOCATION



Location: Sigay Chiwog, Mewang Gewog, Thimphu Dzongkhag, Bhutan

No. of Technology sites analysed: single site

Geo-reference of selected sites
- 449.58953, 27.39046

Spread of the Technology: applied at specific points/ concentrated on a small area

In a permanently protected area?: Nee

Date of implementation: 2022

Type of introduction
- [ ] through land users' innovation
- [ ] as part of a traditional system (> 50 years)
- [ ] during experiments/ research
- [x] through projects/ external interventions

officers and is shared with the Extension Agents through which it is disseminated to the land users.

The photo was taken with the field extension supervisor. (Aum Tshogpa of Sigey Chiwog)

CLASSIFICATION OF THE TECHNOLOGY

Main purpose

- [x] improve production
- [x] reduce, prevent, restore land degradation
- [x] conserve ecosystem
- [ ] protect a watershed/ downstream areas – in combination with other Technologies
- [ ] preserve/ improve biodiversity
- [ ] reduce risk of disasters
- [ ] adapt to climate change/ extremes and its impacts
- [ ] mitigate climate change and its impacts
- [x] create beneficial economic impact
- [x] create beneficial social impact

Land use

Land use mixed within the same land unit: Ja - Agroforestry

Cropland

- Annual cropping: cereals - rice (upland). Cropping system: Wetland rice - wheat
- Perennial (non-woody) cropping

Number of growing seasons per year: 2
Is intercropping practiced? Ja
Is crop rotation practiced? Ja

Water supply

- [ ] rainfed
- [x] mixed rainfed-irrigated
- [ ] full irrigation

Purpose related to land degradation

- [x] prevent land degradation
- [x] reduce land degradation
- [ ] restore/ rehabilitate severely degraded land
- [ ] adapt to land degradation
- [ ] not applicable

Degradation addressed

soil erosion by water - Wt: loss of topsoil/ surface erosion, Wg: gully erosion/ gullying

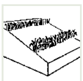
soil erosion by wind - Et: loss of topsoil

biological degradation - Bc: reduction of vegetation cover

SLM group

- agroforestry
- improved plant varieties/ animal breeds

SLM measures

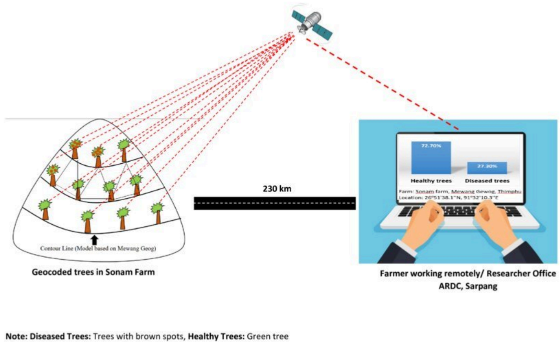


vegetative measures - V1: Tree and shrub cover

TECHNICAL DRAWING

Technical specifications

The technical drawing represents the general method of million fruit tree plantation and geocoding done on each tree. It depicts how geocoding enables the researcher or farmer to remotely check the health of the trees using satellite data. ARDC stands for Agriculture Research and Development Center.



Technical Drawing of the Geocoding of Million Fruit Trees for Monitoring and Tracking

Author: Nima Dolma Tamang, Singye Dorji, Tshering Gyeltshen

ESTABLISHMENT AND MAINTENANCE: ACTIVITIES, INPUTS AND COSTS

Calculation of inputs and costs

- Costs are calculated: per Technology unit (unit: **No of Seedlings** volume, length: **8000 seedlings (Only in Mewang Geog)**)
- Currency used for cost calculation: **Ngultrum (Bhutanese Currency)**
- Exchange rate (to USD): 1 USD = 82.62 Ngultrum (Bhutanese Currency)
- Average wage cost of hired labour per day: 800

Most important factors affecting the costs

Most important factors affecting the costs are seedling and labour cost.

Establishment activities

1. Meeting between Gewog leaders and land users (Timing/ frequency: NA)
2. Identified a village for planation (Timing/ frequency: NA)
3. Identified households that wanted the seedings and number of seedlings (Timing/ frequency: NA)
4. Site identification (Timing/ frequency: NA)
5. Orchard layout (Timing/ frequency: NA)
6. Pit digging (Timing/ frequency: NA)
7. Plantation (Timing/ frequency: March- April)
8. Basin making (Timing/ frequency: After planation)
9. Geocoding (Timing/ frequency: After one month of orchard establishment)
10. Growth Tracking (Timing/ frequency: After every six months)

Establishment inputs and costs (per No of Seedlings)

Specify input	Unit	Quantity	Costs per Unit (Ngultrum (Bhutanese Currency))	Total costs per input (Ngultrum (Bhutanese Currency))	% of costs borne by land users
Labour					
Desuup (Guardians of peace) - Volunteers	Person-days	6.0			
Farmers	Person-days	10.0	800.0	8000.0	100.0
Equipment					
Shovel	No.	10.0			100.0
crow-bar	No.	5.0			100.0
Spade	No.	20.0			100.0
GPS remote	No	6.0	12000.0	72000.0	
Tabs/ mobile phones	No.	6.0	15000.0	90000.0	
Plant material					
Apple	No.	3500.0	70.0	245000.0	
Walnut	No.	1000.0	120.0	120000.0	
Almond	No.	500.0	120.0	60000.0	
Peach	No.	1000.0	70.0	70000.0	
Pear	No.	2000.0	70.0	140000.0	
Fertilizers and biocides					
Manure and fertillizers	Metric Tonnes	16.0	1600.0	25600.0	100.0
Total costs for establishment of the Technology				**830'600.0**	
Total costs for establishment of the Technology in USD				*10'053.26*	

Maintenance activities

1. Weeding (Timing/ frequency: Twice a year)

2. Fertillizer application (Timing/ frequency: Twice a year)
3. Irrigation (Timing/ frequency: Once a week)
4. Replacement of dead plants (Timing/ frequency: After 6 months from plantation)
5. Growth tracking (Timing/ frequency: After every six month)

Maintenance inputs and costs (per No of Seedlings)

Specify input	Unit	Quantity	Costs per Unit (Ngultrum (Bhutanese Currency))	Total costs per input (Ngultrum (Bhutanese Currency))	% of costs borne by land users
Labour					
Weeding and fertilizer application	Per year	4.0	1600.0	6400.0	100.0
Irrigation	Litres				
Geocoding	per plant	8000.0			
Plant material					
Replacement of plants	per plant	10.0	70.0	700.0	
Total costs for maintenance of the Technology				**7'100.0**	
Total costs for maintenance of the Technology in USD				*85.94*	

NATURAL ENVIRONMENT

Average annual rainfall
- [ ] < 250 mm
- [ ] 251-500 mm
- [ ] 501-750 mm
- [ ] 751-1,000 mm
- [ ] 1,001-1,500 mm
- [ ] 1,501-2,000 mm
- [x] 2,001-3,000 mm
- [ ] 3,001-4,000 mm
- [ ] > 4,000 mm

Agro-climatic zone
- [ ] humid
- [ ] sub-humid
- [ ] semi-arid
- [ ] arid

Specifications on climate
Average annual rainfall in mm: 2076.0
The rainfall data for Mewang Gewog is not available. The provided data is for Thimphu Dzongkhag as Mewang Gewog is under Thimphu Dzongkhag (Gewog is one of the geographic units below Dzongkhag). Thimphu falls under a temperate region and experiences minimal rainfall compared to the other parts of Bhutan. Thimphu had the wettest month in July with 497 mm and experienced the least rainfall in December with 5 mm.
Name of the meteorological station: National Center for Hydrology and Metoerology, Thimphu.
There are six Agro-ecological Zones (AEZ) in Bhutan and the current place of study falls under warm temperate zone which occurs between 1,800 – 2,500 m. Rainfall is low but the temperature is moderately warm in summer with frost in winter.

Slope
- [ ] flat (0-2%)
- [x] gentle (3-5%)
- [ ] moderate (6-10%)
- [ ] rolling (11-15%)
- [ ] hilly (16-30%)
- [ ] steep (31-60%)
- [ ] very steep (>60%)

Landforms
- [ ] plateau/plains
- [ ] ridges
- [ ] mountain slopes
- [x] hill slopes
- [ ] footslopes
- [ ] valley floors

Altitude
- [ ] 0-100 m a.s.l.
- [ ] 101-500 m a.s.l.
- [ ] 501-1,000 m a.s.l.
- [ ] 1,001-1,500 m a.s.l.
- [ ] 1,501-2,000 m a.s.l.
- [ ] 2,001-2,500 m a.s.l.
- [x] 2,501-3,000 m a.s.l.
- [ ] 3,001-4,000 m a.s.l.
- [ ] > 4,000 m a.s.l.

Technology is applied in
- [x] convex situations
- [ ] concave situations
- [ ] not relevant

Soil depth
- [x] very shallow (0-20 cm)
- [ ] shallow (21-50 cm)
- [ ] moderately deep (51-80 cm)
- [ ] deep (81-120 cm)
- [ ] very deep (> 120 cm)

Soil texture (topsoil)
- [ ] coarse/ light (sandy)
- [x] medium (loamy, silty)
- [ ] fine/ heavy (clay)

Soil texture (> 20 cm below surface)
- [ ] coarse/ light (sandy)
- [x] medium (loamy, silty)
- [ ] fine/ heavy (clay)

Topsoil organic matter content
- [ ] high (>3%)
- [x] medium (1-3%)
- [ ] low (<1%)

Groundwater table
- [ ] on surface
- [ ] < 5 m
- [ ] 5-50 m
- [ ] > 50 m

Availability of surface water
- [ ] excess
- [ ] good
- [x] medium
- [ ] poor/ none

Water quality (untreated)
- [ ] good drinking water
- [ ] poor drinking water (treatment required)
- [x] for agricultural use only (irrigation)
- [ ] unusable

Water quality refers to: surface water

Is salinity a problem?
- [ ] Ja
- [x] Nee

Occurrence of flooding
- [ ] Ja
- [x] Nee

Species diversity
- [ ] high
- [ ] medium
- [x] low

Habitat diversity
- [ ] high
- [x] medium
- [ ] low

CHARACTERISTICS OF LAND USERS APPLYING THE TECHNOLOGY

Market orientation

Off-farm income

Relative level of wealth

Level of mechanization

- [ ] subsistence (self-supply)
- [x] mixed (subsistence/ commercial)
- [ ] commercial/ market

- [ ] less than 10% of all income
- [x] 10-50% of all income
- [ ] > 50% of all income

- [ ] very poor
- [ ] poor
- [x] average
- [ ] rich
- [ ] very rich

- [ ] manual work
- [ ] animal traction
- [x] mechanized/ motorized

Sedentary or nomadic
- [x] Sedentary
- [ ] Semi-nomadic
- [ ] Nomadic

Individuals or groups
- [x] individual/ household
- [ ] groups/ community
- [ ] cooperative
- [ ] employee (company, government)

Gender
- [x] women
- [ ] men

Age
- [ ] children
- [ ] youth
- [x] middle-aged
- [ ] elderly

Area used per household
- [ ] < 0.5 ha
- [ ] 0.5-1 ha
- [x] 1-2 ha
- [ ] 2-5 ha
- [ ] 5-15 ha
- [ ] 15-50 ha
- [ ] 50-100 ha
- [ ] 100-500 ha
- [ ] 500-1,000 ha
- [ ] 1,000-10,000 ha
- [ ] > 10,000 ha

Scale
- [ ] small-scale
- [x] medium-scale
- [ ] large-scale

Land ownership
- [ ] state
- [ ] company
- [ ] communal/ village
- [ ] group
- [ ] individual, not titled
- [x] individual, titled

Land use rights
- [ ] open access (unorganized)
- [ ] communal (organized)
- [x] leased
- [x] individual

Water use rights
- [ ] open access (unorganized)
- [x] communal (organized)
- [ ] leased
- [ ] individual

Access to services and infrastructure

health	poor			✓	good
education	poor			✓	good
technical assistance	poor			✓	good
employment (e.g. off-farm)	poor		✓		good
markets	poor			✓	good
energy	poor			✓	good
roads and transport	poor			✓	good
drinking water and sanitation	poor		✓		good
financial services	poor			✓	good
Internet	poor			✓	good

Comments

The drinking water is insufficient as some households face scarcity of drinking water.

IMPACTS

Socio-economic impacts

Crop production

	decreased					✓			increased

The technology aids in the monitoring and improves health and ease management of the already established orchard. Therefore, it indirectly increases crop production.

crop quality

	decreased					✓			increased

Remote or constant monitoring ensures timely management to prevent biotic and abiotic factors deteriorate the crop quality.

fodder production	decreased				✓				increased
fodder quality	decreased				✓				increased

risk of production failure

	increased					✓			decreased

Geocoding enables land user to determine potential risk so that the land user can use appropriate methods to prevent crop failure.

product diversity

	decreased						✓		increased

The technology is not directly related to the product diversity. However, it provides data on existing fruit tree diversity so that the land user can plan and plant different fruit trees based on the market need which indirectly increases diversity.

production area (new land under cultivation/ use)

	decreased					✓			increased

Geocoding enables the land user to remotely view the cropped area and the area where the crop failed (could be due to dying of the seedlings/diseased). It enables the land user to narrow their focus on the specific area, learn about the issues causing the crop loss, provide appropriate management, and conduct plantation in that area which indirectly increases production area.

irrigation water availability

	decreased			✓					increased

Due to increased production area with no increase in the quantity of irrigation water, water availability is likely to reduce.

		1	2	3	4	5	6	7		
demand for irrigation water	increased				✓				decreased	There is increased demand for irrigation water for new plantations. However, with the use of technology land users can monitor the water requirement and use efficiently based on the need of the tree whereby the land users can avoid watering the trees that require less water and provide to those that require more water.
expenses on agricultural inputs	increased			✓					decreased	Minimal increase in expenses on agriculture inputs as planting materials (except manure) were provided to the land users for free of cost.
farm income	decreased						✓		increased	Once the fruit trees starts bearing fruits, income is expected to increase.
economic disparities	increased					✓			decreased	The technology is expected to reduce economic disparity by providing equal opportunity for the land users to generate income.
workload	increased							✓	decreased	Workload for the project implementors or land users are significantly reduced as they need not go to the actual site to determine the progress of the Million Fruit Trees Plantation Project.

Socio-cultural impacts

		1	2	3	4	5	6	7		
food security/ self-sufficiency	reduced						✓		improved	The technology indirectly aids in the increased production making an individual land user and the nation self-sufficient in fruits.
recreational opportunities	reduced					✓			improved	With reduced workload, land users can engage in recreational activities.
SLM/ land degradation knowledge	reduced					✓			improved	The technology will enable the project implementors to determine specific knowledge gaps and provide training in that particular field to the land users. Improving knowledge of both project implementors and land users.
situation of socially and economically disadvantaged groups (gender, age, status, ehtnicity etc.)	worsened					✓			improved	Land users willing to be involved in fruit tree plantation are supported without discrimination of their social status or economic background and geocoding services are provided. This leads to the improved situation of socially and economically disadvantaged groups.

Ecological impacts

		1	2	3	4	5	6	7		
water quantity	decreased			✓					increased	The total water quantity remains same. However, the available water per tree or sapling is reduced.
surface runoff	increased					✓			decreased	Due to the absorption of water by the roots of the fruit trees, surface run-off is decreased.
evaporation	increased					✓			decreased	Evaporation will be decreased due to an increase in the vegetation cover from the plantation of the fruit trees.
soil moisture	decreased					✓			increased	Slight increase in the soil moisture in long run due to addition of soil organic matter and monitored irrigation.
soil cover	reduced					✓			improved	The technology enhances easy monitoring of the trees and encourages increased soil cover.
soil loss	increased					✓			decreased	The technology enhances soil cover reducing the soil loss from erosion.
nutrient cycling/ recharge	decreased					✓			increased	Geocoding enables the land user to have overview of the nutrient content of the production area aiding land users to add nutrient based on the need.

soil organic matter/ below ground C

decreased / increased

Generally, there will be an increase in the soil organic matter due to an increase in production area and management practice such as the addition of manures by the land user.

vegetation cover

decreased / increased

Increase due to the scheduled irrigation applied to the fruit trees.

biomass/ above ground C

decreased / increased

Slight increase due to proper management and care provided to the orchard.

animal diversity

decreased / increased

Animal diversity in the case of pollinators such as bees increases as the fruit trees mature and start flowering.

beneficial species (predators, earthworms, pollinators)

decreased / increased

Beneficial species such as bees are attracted to the orchards.

pest/ disease control

decreased / increased

Pest and diseases control improves with the use of remote monitoring facilitated by this technology.

landslides/ debris flows

increased / decreased

Once the fruit trees establish themselves, landslides can be reduced significantly due to vegetation cover.

emission of carbon and greenhouse gases

increased / decreased

This technology could potentially reduce greenhouse gas as trees utilize carbon dioxide for photosynthesis.

wind velocity

increased / decreased

In the long run, a well-established orchard can act as a windbreak and reduce wind velocity and damage it poses to the property.

micro-climate

worsened / improved

An orchard can act as a micro-climate harbouring many plants and insect species.

Off-site impacts

water availability (groundwater, springs)

decreased / increased

Fruit trees require irrigation which reduces the availability of water for other purposes.

impact of greenhouse gases

increased / reduced

Having a land cover with vegetation compared to barren land reduces greenhouse gases.

COST-BENEFIT ANALYSIS

Benefits compared with establishment costs

Short-term returns — very negative / very positive

Long-term returns — very negative / very positive

Benefits compared with maintenance costs

Short-term returns — very negative / very positive

Long-term returns — very negative / very positive

Although the initial establishment of the orchard is costly considering the labour charge, it is expected to have positive income and impact once the fruit trees start bearing.

CLIMATE CHANGE

Gradual climate change

annual temperature increase — not well at all / very well

seasonal temperature increase — not well at all / very well — Season: summer

annual rainfall increase — not well at all / very well

seasonal rainfall decrease — not well at all / very well — Season: summer

Climate-related extremes (disasters)

local hailstorm — not well at all / very well

epidemic diseases — not well at all / very well

ADOPTION AND ADAPTATION

Percentage of land users in the area who have adopted the Technology

- ☐ single cases/ experimental
- ☐ 1-10%
- ☐ 11-50%
- ☑ > 50%

Of all those who have adopted the Technology, how many have done so without receiving material incentives?

- ☑ 0-10%
- ☐ 11-50%
- ☐ 51-90%
- ☐ 91-100%

Number of households and/ or area covered

Total 8000 fruit trees are planted in the five Chiwogs (third level administrative division under Gewog) under Mewang Gewog.

Has the Technology been modified recently to adapt to changing conditions?

- ☐ Ja
- ☑ Nee

To which changing conditions?

- ☐ climatic change/ extremes
- ☐ changing markets
- ☐ labour availability (e.g. due to migration)

CONCLUSIONS AND LESSONS LEARNT

Strengths: land user's view

- 1. Precision Mapping: Geocoding allows for accurate mapping and identification of fruit trees. By assigning specific geographic coordinates to each tree, it becomes easier to locate and monitor individual trees or orchards.
- 2. Efficient Resource Allocation: Geocoding helps optimize resource allocation by providing information on tree density and distribution. Land users can identify areas with high fruit tree concentrations and strategically allocate resources such as labour, water, fertilizers, and pesticides, leading to improved productivity and reduced costs.
- 3. Data-driven Decision Making: Geocoded data on fruit trees can be analyzed to gain insights into their distribution patterns, growth rates, and health status. This information enables land users, researchers, and policymakers to make informed decisions regarding fruit tree cultivation, pest control, and disease management.

Strengths: compiler's or other key resource person's view

- 1. Conservation and Biodiversity Analysis: Geocoded fruit tree data aids in the conservation and analysis of biodiversity. By mapping the locations of different fruit tree species, experts can assess the distribution and abundance of specific varieties, identify endangered local or traditional landraces varieties, and develop strategies for their preservation.
- 2. Targeted Marketing and Distribution: Geocoded fruit tree data facilitates targeted marketing and distribution strategies. By understanding the location of fruit trees and their yields, producers can identify potential markets and plan transportation logistics more effectively, minimizing waste and ensuring timely delivery to consumers.

Weaknesses/ disadvantages/ risks: land user's viewhow to overcome

- Geocoding large numbers of fruit trees can be a time-consuming and resource-intensive task, particularly when manual processes are involved. It may require extensive fieldwork and manual data entry, making it impractical or costly for large-scale fruit tree inventories.
- Privacy Concerns: Geocoding fruit trees raises privacy concerns, particularly when tree locations are associated with specific individuals or properties. Care must be taken to ensure that privacy is respected and sensitive information is appropriately handled An updated and secured security-protected website can be used.
- Lack of knowledge of geocoding by the farmers. Provide awareness trainings

Weaknesses/ disadvantages/ risks: compiler's or other key resource person's viewhow to overcome

- The higher expense of the geocoding in terms of labour cost for geo-coding Train land users on geocoding, instead of using trained professionals.
- Difficult to constantly update information on time.

REFERENCES

Compiler
Nima Dolma Tamang

Editors
Haka Drukpa

Reviewer
William Critchley
Rima Mekdaschi Studer
Joana Eichenberger

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Resource persons
Thuji Penjor - Agriculture Extension Officer

Full description in the WOCAT database
https://qcat.wocat.net/af/wocat/technologies/view/technologies_6829/

Linked SLM data
n.a.

Documentation was faciliated by

Institution
- National Soil Services Center, Department of Agric (National Soil Services Center, Department of Agric) - Bhutan

Project
- Strengthening national-level institutional and professional capacities of country Parties towards enhanced UNCCD monitoring and reporting – GEF 7 EA Umbrella II (GEF 7 UNCCD Enabling Activities_Umbrella II)

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