Integrating Remote Sensing Technology to Enhance the Geomapping System of the Philippine Rural Development Project (PRDP) for Precise Decision-Making in Farm-to-Market Road Investments

USERS' GUIDE

I. Introduction

The Philippine Rural Development Project (PRDP) is one of the flagship programs of the Department of Agriculture designed to address the gaps in the commodity value chains by improving the efficiency of the food supply chain towards greater connectivity, mobility, accessibility, availability, and affordability of food in the market.[1]

Interventions include rebuilding the whole value chain, improving the food supply chain and logistics, prioritizing farm-to-market roads (FMRs) with value chain infrastructure support, including rice and corn focusing on value addition, and mainstreaming of institutional reforms in the DA programs and projects. One of the key interventions of the project is the construction of farm-to-market roads (FMRs) with value chain infrastructure support across the country.

The PRDP has a huge portfolio of Farm-to-Market Road (FMRs) and FMRs with Bridge, amounting to Php 63 Billion or 83% of the overall total investments of the Project for rural infrastructure or equivalent to 528 subprojects and 4,000 kilometers that are expected to be built across all 16 regions and 82 provinces in the Philippines by the year 2028.

Table 1. Infrastructure Portfolio by Type as of May 05, 2023

Type of Subprojects	Number of Subprojects	Unit Measure	Quantity	Total
Farm to Market Road (FMR)	448	Kilometer	3,248.34	47,729,776,564.50
FMR with Bridge	80	Kilometer	760.40	15,376,821,635.95
Bridge	40	Hectare	3,801.66	552,972,612.54
Potable Water Supply (PWS) Level 2	95	Number of Households	70,406	3,172,623,986.51
Others	311	Square Meter	317,827.53	8,500,382,862.79
Total	986			75,956,424,892.89

To effectively manage the subprojects of the PRDP, given the limitation and resource requirement for regular physical site visits. The [2]Geomapping System was established as a web-based platform to serve as a Decision Support Tool (DST) to efficiently manage, process and store geospatial data and information. This system is in-house developed with the purpose to address challenges in subproject validation, implementation, monitoring, and evaluation. The system features include the expanded Vulnerability and Suitability Assessment, Integrated Roads on Agri-Fishery Development (i-ROAD) System, Road Influence Area Mapping, web-based geotagging technology, and Unmanned Aerial Vehicle (UAV) or drone utilization. Further, the pandemic crisis pushed the project to utilize the Geomapping System as an effective alternate mode for doing field visits and reviewing FMR proposals.

The Expanded Vulnerability and Suitability Assessment (eVSA). The eVSA helps planners determine the relative suitability of a commodity in a province and ranks respective municipalities according to its best fit agro-edaphic qualities.

The Integrated Roads on Agri-Fishery Development (i-ROAD) System provides an interactive platform for consolidating the FMR database and creating an FMR dashboard for real-time monitoring and geospatial analysis for more informed decision-making.

1Philippine Rural Development Project (PRDP) Scale-Up, Frequently Asked Questions and PRDP Infrastructure Portfolio, www,prdp.da.gov.ph, May 2023.

2 A spatial mapping technique used to represent geographic data (i.e., agricultural patterns, crop production, and land suitability) into an online interactive visual map that aids in targeting and prioritizing development interventions.

The Applied Geotagging Tool (AGT) has strengthened transparency and accountability mechanisms as it is able to deter overlapping proposals, insubstantial road influence area, overestimation of data, and duplication/parallelism to existing roads ensuring cost-efficient investments.

Despite this technological advancement, the Philippine Rural Development Project (PRDP) and the Department of Agriculture as a whole are still facing limitations in providing real-time evidence-based information related to farm-to-market road (FMR) investments particularly to produce precise geospatial data on land use classification, land cover changes, and crop delineation of specific infrastructure investments which is vital in planning and evaluation of project impacts to the agriculture sector.

Lastly, in instances where climate externality occurs in the Project's coverage areas the limitation to quickly provide real-time or on-demand information on the extent of damages to infrastructures and agriculture areas is quite a challenge.

II. Problem Statement

Despite the establishment of a Geomapping System, the Department of Agriculture- Philippine Rural Development Project (PRDP) is still facing limitations in generating evidence-based information for decision-making related to farm-to-market road (FMR) investments due to a lack of precise geospatial data on land use classification, land cover change analysis, and crop delineation. For instance, the existing system will not be able to answer crucial information such as the following:

1. How many areas of agricultural land have been supported by the Project based on funded FMR?
2. Did the farmer-beneficiaries located in this agricultural area expand their land for agricultural production and related activities?
3. How much investment in PRDP-FMR has been implemented towards the improvement in the value chain of priority commodities?
4. In the case of climate vulnerability, where are the investments that are most affected by typhoons, flooding, and landslide? Are climate mitigation strategies applied to these investments?

The absence of the above information hinders the effective planning, monitoring, and evaluation of FMR projects. Integrating remote sensing technology into the PRDP's geomapping system could address these limitations and provide accurate and real-time information on infrastructure and crop areas, ultimately improving the efficiency and effectiveness of FMR investments.

Furthermore, the Project would like to avoid proposals that will not exhibit benefits to address the gaps in the commodity value chains, particularly the food supply chain from production areas to the market and or the consumer's table. A concrete example in Figure 1, can be observed that the FMR constructed was along a built-up area (left), and recent satellite imagery (right) would suggest that residential subdivisions are developing within the vicinity.

Figure 1. Virtual visits of DA-regular funded FMR using geotagging photos and google earth imagery 2011 vis-a-vis 2016

III. Methodology

Remote Sensing technology can provide precise and real-time data on land use classification, land cover change analysis (before and after scenario), and crop delineation in specific FMR sub-project. In order to address the limitations in generating the above information for decision-making related to farm-to-market road (FMR) investments, the DA-PRDP should consider integrating remote sensing technology into the existing Geomapping System. It is recommended that the following enumerated steps below will be conducted to achieve the proposed integration.

(i) To select appropriate remote sensing procedures and available satellite data that can generate precise land use classification, land cover change analysis, and crop delineation.

(ii) To generate an initial result and an overall analysis, to potentially address the information gap requirement.

(iii) To determine the potential integration of generated results on land use classification, land cover change analysis, and crop delineation using the Geomapping System.

A. Study Area and Data

a. Study Area

This research intends to cover the 16 regions of the Project areas across the country, with a total number of 515 FMR Projects that have polyline data (shp file) in the Geomapping System database. Figure 2 and Figure one showcased the specific locations and list of FMRs by Region, to capture the entire picture of the study area.

Figure 2. Map of the specific location of the PRDP FMR in the IROAD database.

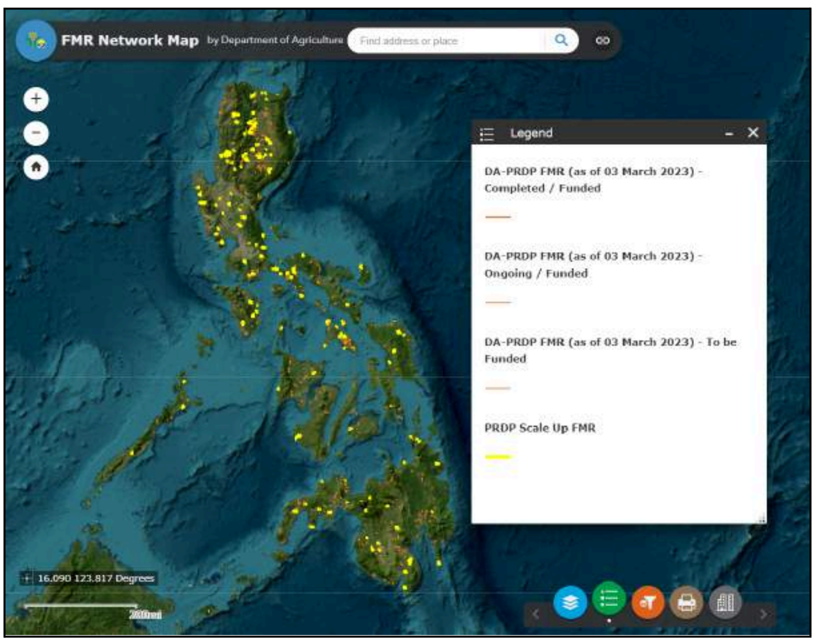


Table 2. No. of FMR Projects by Region

Region	Farm to Market Road (FMR)	FMR with Bridge	Total
BARMM	21	1	22
CAR	32	8	40
Region I	7	5	12
Region II	39	8	47

Region III	32	4	36
Region IV-A	38	5	43
Region IV-B	17	10	27
Region V	30	2	32
Region VI	41	13	54
Region VII	15	6	21
Region VIII	12		12
Region IX	23	2	25
Region X	41	3	44
Region XI	23	6	29
Region XII	44		44
Region XIII	22	5	27
Total	437	78	515

b. Remote Sensing Data

The classified Land Use/Land Cover Sentinel-2 imagery at 10m resolution, was obtained from the ArcGIS living atlas repository (https://livingatlas.arcgis.com). The Land Use/Land Cover (LULC) is derived from ESA Sentinel-2 imagery at 10m resolution, generated from Impact Observatory's deep learning AI land classification model used a massive training dataset of billions of human-labeled image pixels developed by the National Geographic Society. The global maps were produced by applying this model to the Sentinel-2 scene collection on Microsoft's Planetary Computer, processing over 400,000 Earth observations per year.

The map was produced by a deep learning model trained using over 5 billion hand-labeled Sentinel-2 pixels, sampled from over 20,000 sites distributed across all major biomes of the world. The underlying deep learning model uses 6 bands of Sentinel-2 surface reflectance data: visible blue, green, red, near-infrared, and two shortwave infrared bands. To create the final map, the model is run on multiple dates of imagery throughout the year, and the outputs are composited into a final representative map for each year.

The processing platform was accessed via Microsoft's Planetary Computer and scaled using Microsoft Azure Batch.

The year 2017 has a land cover class assigned for every pixel, but its class is based upon fewer images than the other years. The years 2018-2021 are based upon a more complete set of imagery. For this reason, the year 2017 may have less accurate land cover class assignments than the years 2018-2021.

Variable mapped: Land use/land cover in 2017, 2018, 2019, 2020, 2021
Data Projection: Universal Transverse Mercator (UTM)
Mosaic Projection: WGS84
Extent: Global
Source imagery: Sentinel-2
Cell Size: 10m (0.00008983152098239751 degrees)
Type: Thematic
Source: Esri Inc.
Publication date: January 2022

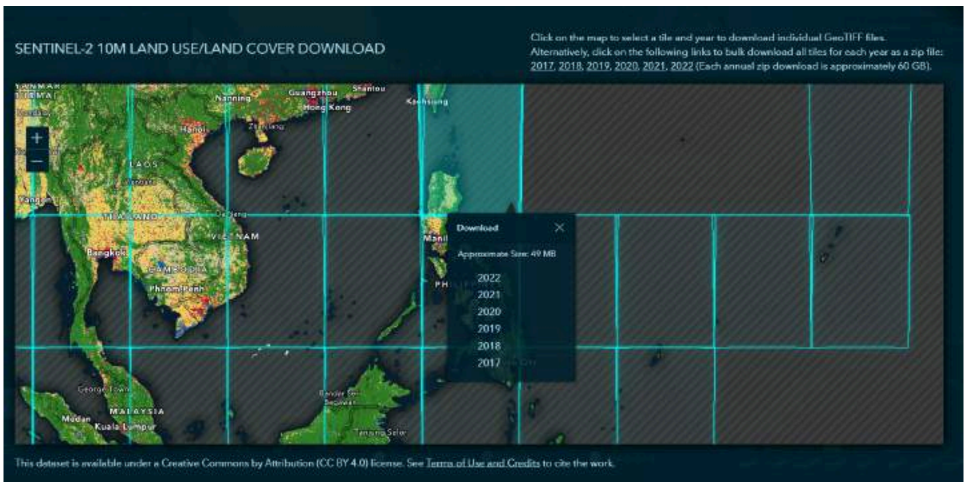
Documentation: https://www.arcgis.com/home/item.html?id=d3da5dd386d140cf93fc9ecbf8da5e31

c. Procedure and techniques

1. Installed the QGIS Desktop 3.28.4 (stable version) to a Windows laptop
2. Downloaded the latest dataset (2022) on Sentinel-2 10M Land Use/Land Cover of the Philippines from www.livingatlas.argis.com. To generate the entire country, download the eight-tile datasets to wit:

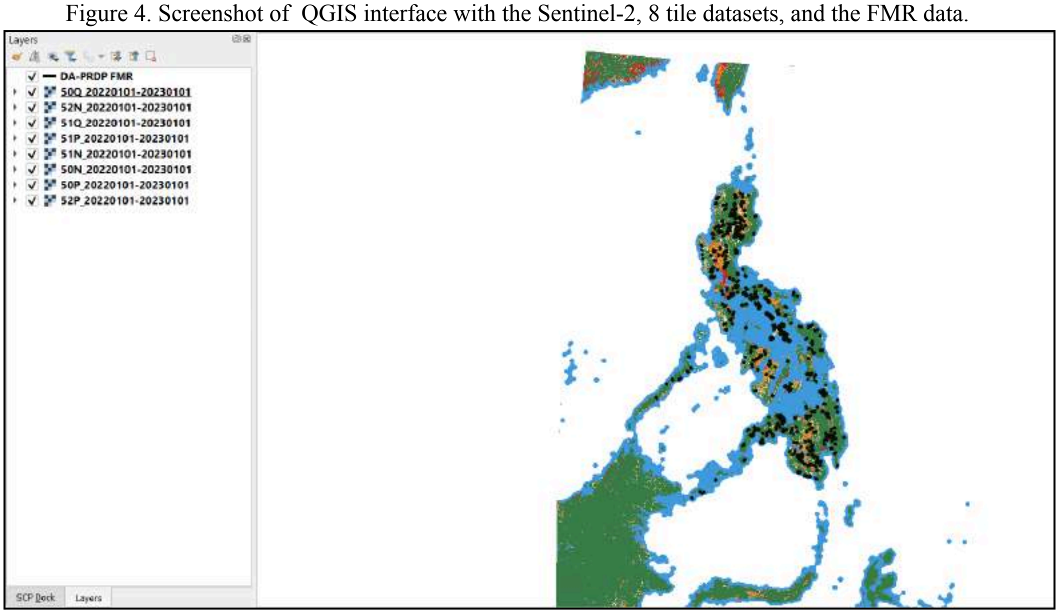
   - 51Q_20220101-20230101
   - 51P_20220101-20230101
   - 51N_20220101-20230101
   - 50Q_20220101-20230101
   - 50P_20220101-20230101
   - 50N_20220101-20230101
   - 52P_20220101-20230101
   - 52N_20220101-20230101

Figure 3. Screenshot of www.livingatlas.argis.com interface for Sentinel-2 10M LU/LC Download



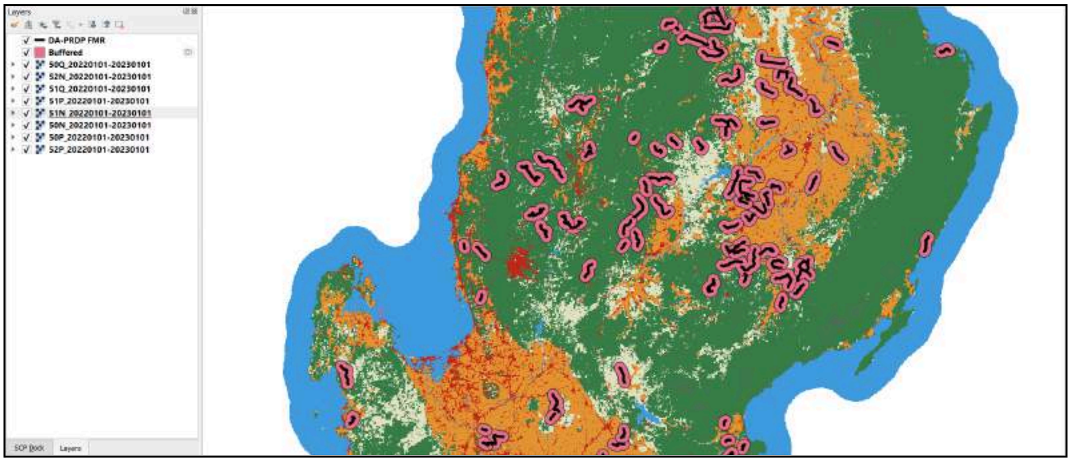
3. Load the eight (8) tiles Sentinel-2 10M LU/LC dataset and the Farm-to-Market Road File to QGIS 3.28.4, as seen in Figure 4.

Figure 4. Screenshot of QGIS interface with the Sentinel-2, 8 tile datasets, and the FMR data.



4. To generate the expected area that a farm-to-market road will most likely impact and generate economic benefits, a 2.5 km buffer to represent the Road Influence Area (RIA) was generated for each FMR[3]. In QGIS, the FMR vector data were processed using a geoprocessing tool to set and generate the 2.5km band through the buffer feature. Results can be seen in Figure 5, below.

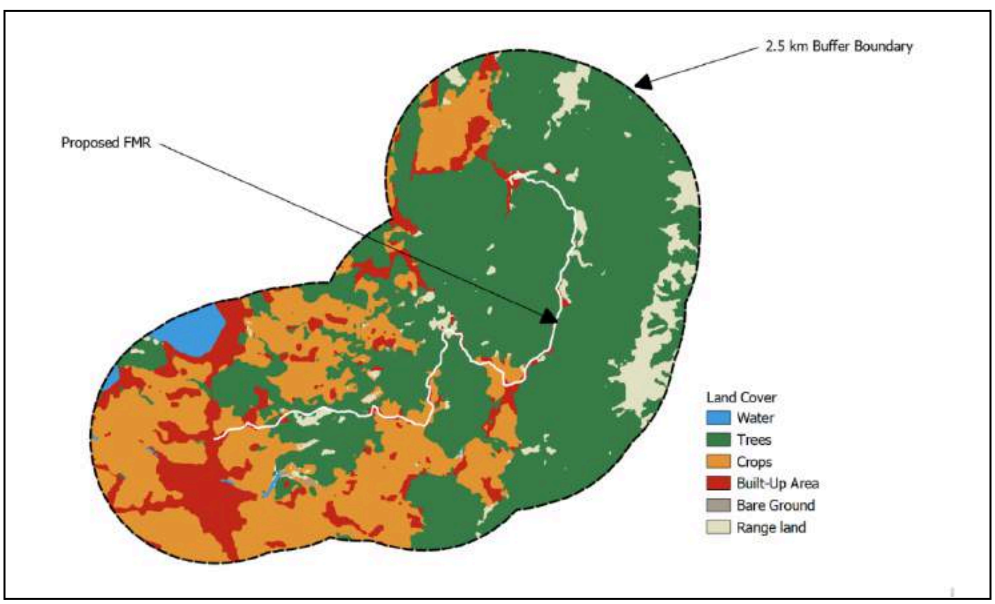
Figure 5. Screenshot of 2.5km band of each FMR vector data



5. The resulting 2.5km band of each FMR vector data, was then clipped to the sentinel 2 classified Land Use/Land Cover Sentinel-2 imagery at 10m resolution. Utilizing the clip raster with the polygon in the QGIS Processing Toolbox.

6. The final output will provide a clipped classified map of sentinel 2 LU/LC imagery of FMR subproject of the PRDP covering the 2.5km buffer as RIA. The land cover classification includes water, trees, crops, built-up area, bare groun,d and range land.

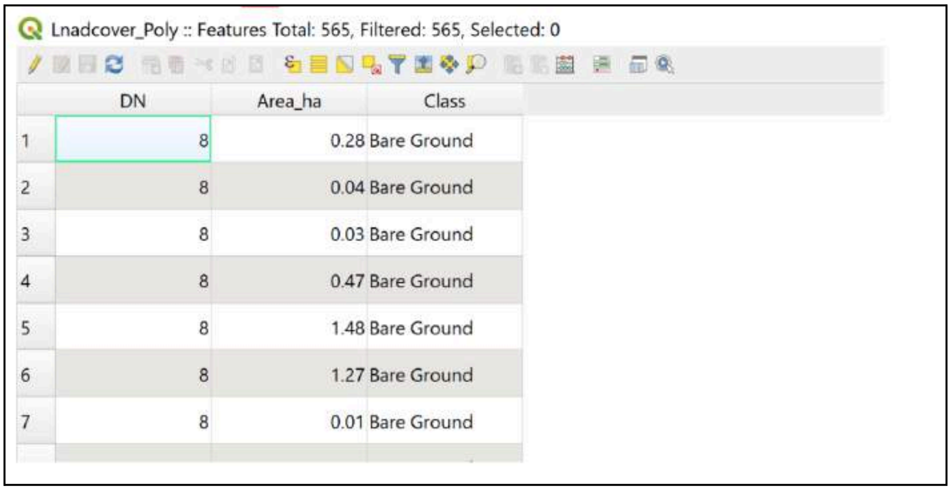
Figure 6. The generated output of one of the FMRs subjected to the procedure and technique



3The RIA is the area that an FMR is expected to effectively service to ensure that the value of investments in an FMR will be much more beneficial than costly. The Project will be utilizing a 2.5-kilometer band (length of the band to be laid out on geo-mapping tools such as Geographic Information System (GIS) and AGT) from both sides of the road to estimate its area of influence.- PRDP RIA Guidelines.

7. Data from each of the final outputs were generated to compute the land area per classification and to compare each class in terms of land areas. Each number in the "DN" of the classified maps corresponds to land cover, which by then computed using the field calculator.

Figure 7. Sample DN by class and area in hectares



Lnadcover_Poly :: Features Total: 565, Filtered: 565, Selected: 0

	DN	Area_ha	Class
1	8	0.28	Bare Ground
2	8	0.04	Bare Ground
3	8	0.03	Bare Ground
4	8	0.47	Bare Ground
5	8	1.48	Bare Ground
6	8	1.27	Bare Ground
7	8	0.01	Bare Ground

d. Results and Integration to the Geomapping System

Initially, only a total of 25 FMR vector data were statistically computed in 5 regions including ARMM, Region I, III, IV-B, XI, and XII due to millions of data being generated and needing some time to process through big query software. Below in Table 3, is the breakdown of No. of FMR projects by region that completed the land cover classification at a 2.5-kilometer buffer.

Table 3. No. of FMR data processed by Region

Region	No. of FMR Data Processed
ARMM	1
Region I	1
Region III	3
Region IV-B	8
Region XI	8
Region XIII	4
Grand Total	**25**

In terms of land cover by area results, the data provides an indication of the distribution and relative importance of different land cover classes in the region which be useful for understanding the location of the funded Farm-to-Market Road in both environmental and economic contexts in the agriculture sector. Below is the land cover class in hectares in the 5 regions.

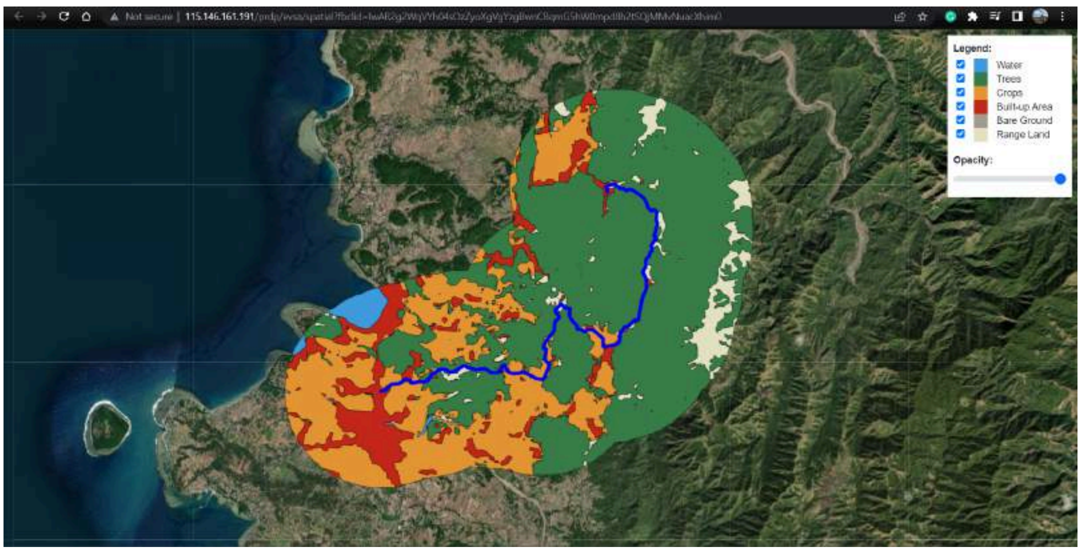
Table 4. Land Cover Class by Region in Hectares (Area)

Region	Bare Ground (in has)	Built-up (in has)	Clouds (in has)	Crops (in has)	Flooded Vegetation (in has)	Range Land (in has)	Trees (in has)	Water (in has)
ARMM		63.876	0.918		0.28	3.096	4254.846	2647.052
Region I	2.056	607.776		946.542		1166.886	375.208	60.068

Region III	0.3	1582.578		535.19	0.05	580.95	1239.934	2821.942
Region IV-B	53.616	1529.724	5.736	667.28	292.622	2390.98	1503.878	16767.664
Region XI	32.212	1901.72	0.04	1251.487	0.729	549.54	10031.866	3938.444
Region XIII	5.271	698.779	0.35	827.454	7.36	399.396	6899.581	3791.142
Grand Total	**93.455**	**6384.453**	**7.044**	**4227.953**	**301.041**	**5090.848**	**24305.313**	**30026.312**

The integration of the resulting classified image to the geomapping system of the DA-PRDP, was successful and currently being improved through the web mapping feature of the system. The enhanced geomapping system will be rolled out at the end of the year including new features on remote sensing technology. Figure 8 uploaded the result of the classified image of a farm-to-market road to the server of the geomapping system.

Figure 8: Integration/uploading of the land use classification results to the Geomapping System (Click to access result)



IV. Initial Results

From the initial processing and generated results, integrating remote sensing technology in the Geomapping System of the Philippine Rural Development Project (PRDP) can be considered as a promising solution to further improve the accuracy and precision of geospatial data to make a more informed decisions related to FMR investments.

The complementation of remote sensing technology with the existing Expanding Vulnerability and Suitability Assessment (eVSA), Applied Geotagging Technology, Unmanned Aerial Vehicle (UAV), and Geographic Information will definitely provide robust datasets of geospatial information that are essential in planning, monitoring, and evaluation of FMR projects.

The utilization of Land Use/Land Cover (LULC) Sentinel-2 imagery at 10m resolution and the existing guidelines in generating road influence area of Farm-to-Market Road has provided an accurate image classification and automated analysis on the extent of land use by classification, which was previously difficult to obtain using the existing geomapping system alone. The information generated can further be processed to help in identifying commodity areas supported by the Project, and can also serve as a basis for evaluating the impact of FMR projects in the agriculture sector.

The use of drones and Applied Geotagging Tool (AGT), is also useful in documenting areas affected by natural disasters such as typhoons, flooding, and landslides. These tools can then be utilized to compare the before and after satellite images of the affected areas, enabling the project to respond and prioritize the rehabilitation of FMRs in the affected areas.

Furthermore, the integration of remote sensing technology into the Geomapping System will improve the accuracy and precision of data, enabling stakeholders to make more informed decisions related to FMR investments. This technology can also be used to provide real-time information in the rapid response to climate externality occurrence, determining potential damage to infrastructure and agriculture areas.

V. Conclusion

In conclusion, integrating remote sensing technology into the Geomapping System of the Philippine Rural Development Project (PRDP) is a promising solution for generating precise and real-time information, enabling robust datasets of geospatial information for decision-making related to farm-to-market road (FMR) investments. This technology can provide solutions to the limitations previously faced by the Project in generating evidence-based information and can ultimately improve the efficiency and effectiveness of FMR investments toward sustainable rural development.

VI. Future Work

In integrating remote sensing technology into Geomapping System as an added layer of science-based information, the Project should consider incorporating guidelines on the use of remotely sensed satellite imagery as a tool to derive relevant information for planning, monitoring, and impact assessment of FMR. Also, it is important to capacitate PRDP's technical staff on the processing, utilization, and analysis of remotely sensed data to ensure appropriate use and interpretation. Lastly, to ensure that geomapping system will be effective and efficient, continuous evaluation and monitoring of the system's performance should be regularly carried out to meet the project objectives and contributes to its overall success.

Moreover, completion of the statistical computing of the remaining FMRs to be processed will be continued to generate the desired analysis and to process year-on-year data to develop a land use trend analysis. And to explore drone technology and photogrammetry in the delineation of crops in the Road Influence Area of the FMRs.

VII. Reference

Karra, Kontgis, et al. "Global land use/land cover with Sentinel-2 and deep learning." IGARSS 2021-2021 IEEE International Geoscience and Remote Sensing Symposium. IEEE, 2021.

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