REVIEW ARTICLE

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SATELLITE REMOTE SENSING OF RICE CROPS IN NEPAL : A REVIEW

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ABSTRACT

Remote sensing, based on satellite data, is useful in studying rice crops for their several parameters such as cropped area, crop-coverage, growth stages, production, yield estimation and other statistics useful in scientific investigations. Despite some satellite-remote-sensing based researches have been reported in the country, such appliance in agricultural studies is very sparse in Nepal. In the current situation, Nepal could benefit from remote sensing technology for betterment of its agricultural planning and development specifically in the rice sub-sector for its national economic and food security importance. This review article is an attempt to highlight the importance of rice remote sensing in Nepal and list research articles in the field as bookmarks to benefit future rice researchers and interested readership.

1. INTRODUCTION

Remote sensing is the scientific technology to acquire physical characteristics of distant objects by the measurement of the reflected and emitted spectral information (USGS, 2022). The radiation collected as the spectral information from sensors mostly based in satellite, aircraft or flying bodies, such as drones, enables the ability to observe larger areas of the surface. Such prepared information over longer duration, even more than a decade, adds advantage to study the changes in the area. These are useful in studying the changes induced by humans in different landscapes and ecosystems (Kerr & Ostrovsky, 2003). Unlike other sensors, the benefits of satellite remote sensing are its readiness and free availability from the providers which has been used in multiple areas including agriculture and crop studies, and importantly in rice crops (Corvino *et al*., 2018).

Remote sensing in agriculture is used in crops monitoring as an assistive tool for decision making even at the farm level (Gao, 2021; Hatfield *et al*., 2020). Remote sensing aids in crop yield estimation process, management of the crops in drought and unpredicted weather conditions and proper policy planning for betterment of crops and agriculture in direct relations with food security (Kumar *et al*., 2022). The benefits of remote sensing are in its beneficial involvements in different crop stages for proper optimization of the yield whose research trends are increasing in current years (Khanal *et al*., 2020).

Application of remote sensing in rice has been increasing since mid 2000s with the MODIS sensors data (due to its easy access and with its higher temporal resolution or its ability to acquire the image every one or two days) and the main research objectives of rice remote sensing have been in retrieval and study of the rice characteristics such as Leaf Area Index (LAI), nitrogen and chlorophyll contents, biomass which have the guiding roles in the rice agronomic managements (Xu *et al*., 2022). The research publications are mostly seen from the developed nations that includes the United States of America (USA), China and Japan, but genuinely, the remote sensing has been boon in other nations as well for monitoring of rice crops mainly for the crop mapping (DDNS, 2016; Tiwari *et al*., 2021; Torres, 2022).

Multiple objectives of rice remote sensing can be surely pointed depending on what satellite sensors and spectral information are being used such as observing rice plant diseases, methane emissions from rice fields,

and rice growing ecosystem as pointed by Kuenzer & Knauer (2013), but the primary goals of the rice remote sensing are rice mapping and the yield estimation. Rice mapping simply are the process to delineate the rice growing areas where multiple methods are applied, including but not limited to, using vegetation indices (mathematical operations of the different spectral bands), radar backscatter (reflectance of microwave portion from the rice growing area) and phenology based approaches from different rice growing stages (Dong & Xiao, 2016). For the rice yield estimation, different models are developed, where satellite generated parameters are empirically related with the yield with current innovative algorithms of machine learning and deep learning (Torre *et al*., 2021).

2. A BRIEF HISTORY

The history of the agriculture remote sensing dates as early as 1970s or even before, but the use of satellite remote sensing can be formally dated with the launch of Landsat-1, which was used for the estimation of wheat production under the project Large Area Crop Inventory Experiment (LACIE) (Macdonald, 1984). With similar aims in Europe in 1988, the Monitoring Agriculture using Remote Sensing (MARS) was launched for estimation of crop yield. By the 1990s, radar based satellite sensors were already launched, whose additional advantages were over its use in the clouds, as microwave energy could penetrate over the clouds, and were used in the studies of rice phenology, rice acreage estimation and rice biophysical parameters (Macdonald, 1984).

History of satellite remote sensing in Nepal dates back with the use of the satellite imageries in the map preparation such as demographic maps in 1991 (Oli, 2002). The potential of remote sensing was long realized for the sensitive ecology of the Himalayan region of Nepal (Millette *et al*. 1995). National Remote Sensing Centre (NRSC) of Nepal was established in 1981, by the cooperation between the then government of Nepal and USAID, which merged with the Forest Survey Division in 1989 and has worked since then for monitoring of forest resources (Juwa, 2009). The noteworthy initiation of application of remote sensing in agriculture can be pointed to the Agriculture Inventory Project of Nepal in the 1980s. However, the project itself had slight or no importance towards the agricultural aspects, and the full exploration of remote sensing in crop studies is still ambiguous (Johnson *et al*., 1984).

3. CURRENT ACTIVITIES IN NEPAL

Current rice remote sensing activities, including other crops, have been mainly performed by International Centre for Integrated Mountain Development (ICIMOD) such as the observation of drought conditions in the agricultural lands (SERVIR, 2016) and the training for crop monitoring using satellite remote sensing aimed at agriculture officials (SERVIR, 2014). The praiseworthy activity is in the ICIMOD's joint approach with Ministry of Agricultural and Livestock Development (MoALD) of Nepal in developing the crop agricultural statistics using the satellite data with machine learning methods, while ICIMOD's important goal has constantly been in aiming to uplift technological capacity of MoALD in Nepal (Qamer *et al*., 2023).

4. LISTABLE WORKS

Discussing the approaches applied in the rice remote sensing will still be early in the context of Nepal. Due to limited works being conducted and the remote sensing works yet to be seen, the best will be still to list the available published works.

The current works can be suggestively divided into three main groups:

- works done for the rice mapping and yield estimation precisely done for Nepal (Table 1),
- works done with the similar goals but not aimed particularly for Nepal, but includes Nepal in the research process (Table 2), and
- works involving rice and some aspects of satellite remote sensing in Nepal but include broader themes not being limited to rice mapping and yield estimation (Table 3).

No particular search method was applied in search of the research articles, which were rather collected during personal studies of the author. Title of the article with distinct object identifier (doi) along with the publication year has been provided as the bookmarked list in table 1, 2 and 3 as grouped in three main sections. Short phrases as the brief, generalising the research works, have been provided, but the interested readers still need to seek each article for comprehensive understanding of the methods applied.

Table 2. presents the research mainly done for the South Asian countries and includes Nepal as one of their study areas.

Table 1. Rice Mapping and Yield Prediction precisely done for Nepal

Title. doi	Year	Brief
Temporal changes in rice-growing area and their impact on livelihood over a decade: A case study of Nepal. https://doi.org/10.1016/j.agee.2011.06.010	2011	rice mapping from MODIS sensor from 2000 to 2010
Operationalizing crop monitoring system for informed decision making related to food security in Nepal. http://dx.doi.org/10.5194/isprsarchives-XL-8-1325-2014	2014	rice crop area estimation of terai districts of 2013 and 2014
Sentinel-2 Multi-Temporal Data for Rice Crop Classification in Nepal. https://doi.org/10.1109/IGARSS39084.2020.9323771	2020	deep learning methods for the preparation of the rice maps
Tracking the dynamics of paddy rice cultivation practice through MODIS time series and PhenoRice algorithm. http://dx.doi.org/10.1016/j.agrformet.2021.108538	2021	preparation of the rice map of Nepal from 2003 to 2018
Rice-Yield Prediction with Multi-Temporal Sentinel-2 Data and 3D CNN: A Case Study in Nepal. https://doi.org/10.3390/rs13071391	2021	deep learning method for the rice yield predictions of terai districts
Mapping Spatial Distribution Of Main Season Rice Fields In Eastern Nepal Using Multi-Temporal Landsat 8 Images. http://doi.org/10.26480/bda.01.2021.01.05	2021	rice mapping of Sunsari and Morang district using Landsat data
Rice Modeling Using Long Time Series of High Temporal Resolution Vegetation Indices in Nepal. https://doi.org/10.1109/Agro-Geoinformatics55649.2022.9858981	2022	relating vegetation indices with the rice yield through modelling approaches

Table 2. Rice Mapping and Yield Prediction done for South Asian countries

Title. doi	Year	Brief
Mapping paddy rice agriculture in South and Southeast Asia using multi-temporal MODIS images. https://doi.org/10.1016/j.rse.2005.10.004	2005	rice mapping of South Asian countries
Integrating remote sensing, census and weather data for an assessment of rice yield, water consumption and water productivity in the Indo-Gangetic river basin. http://dx.doi.org/10.1016/j.agwat.2009.09.021	2009	relates satellite based parameters with the yield
Mapping rice areas of South Asia using MODIS multitemporal data. https://doi.org/10.1117/1.3619838	2011	rice mapping of South Asian countries
Mapping of rice-cropping pattern and cultural type using remote-sensing and ancillary data: a case study for South and Southeast Asian countries. https://doi.org/10.1080/01431161.2015.1110259	2015	rice mapping of South Asian countries
Rice Grain Yield Estimation Over Some Asian Countries Using Isro's Scatsat-1 Ku-Band Scatterometer Data. https://doi.org/10.5194/isprs-archives-XLII-3-W6-257-2019	2019	rice yield estimation using microwave based sensors

Table 3. presents the research done with the broader themes in which specific location of the study has been chosen within Nepal. The research can be seen mostly aligned with the climate change and the trends of the crop production in the years. Rice has also been studied along with remote sensing based crop cycle observation.

Table 3. Remote Sensing with broader themes

Title. doi	Year	Brief
Rice and Bricks: Environmental Issues and Mapping of the Unusual Crop Rotation Pattern in the Kathmandu Valley, Nepal. https://doi.org/10.1007/s00267-006-0167-0	2007	uses satellite imagery to observe the brick kilns, observes their impacts in the crop production
Climate Change Impact and Adaptation Practices in Agriculture: A Case Study of Rautahat District, Nepal. https://doi.org/10.3390/cli4040063	2016	uses satellite derived moisture data with other data to observe the trends of the crop production
Crop Cycles and Crop Land Classification in Nepal Using MODIS NDVI. https://doi.org/10.1007/s41976-018-0002-4	2018	observation of the crop cycle based on MODIS sensor
Impact of climate change on agricultural productivity and food security in the Himalayas: A case study in Nepal. https://doi.org/10.1016/j.agsy.2019.01.008	2019	observation of the future crop production trends
RICA: A rice crop calendar for Asia based on MODIS multi year data. https://doi.org/10.1016/j.jag.2021.102471	2021	preparation of rice crop calendar using remote sensing data
Land Cover Change and Its Impact in Crop Yield: A Case Study from Western Nepal. https://doi.org/10.1155/2022/5129423	2022	observation of the impacts of the land cover change in the crop production

For the further summary of the research, few of the things can be highlighted as seen from the list of the research.

- MODIS sensor based satellite data is found to be most used in most of the research.
- Satellite generated data such as soil moisture data can also be seen in the research with the main objectives of studying the crop future trends.
- Very few affiliations of the authors in the research article are from within Nepal emphasizing the sparse research status of the country although the involvements of the Nepalese authors in the works are admirable.
- More research works are still to be seen involving satellite based rice remote sensing in Nepal.

5. CONCLUSION

To summarize, the direct advantage of satellite remote sensing is in its generation of the crop related statistics. In the current contexts of rice imports in increasing trends within Nepal, satellite remote sensing will be a guiding tool to observe the nation's rice statistics closely.

Suggestions from the research findings are pointable much towards the improvement and more participation of Nepalese institutions in the remote sensing based applications. In the current situation of the country, rice remote sensing based on other tools such as drones or aerial based remote sensing cannot fully be cost friendly compared to satellite remote sensing. More emphasis should be put on the use of satellite remote sensing and the currently freely available platforms such as earth engine or planetary computer are still applicable for the institutional needs within the country. And in the continuously developing geospatial domain with more earth observation satellites being launched, Nepal can use those data in the studies of its crops like rice. For this, interests from all the institutions within Nepal, and interested individuals should be jointly involved.

The other blessings of being concentrated in the rice remote sensing will be towards the shared methods applicable toward the other crops of Nepal. This will be surely observable if more and more technicalities within the rice remote sensing are functional and these processes start containing the other crops as well. In coming decades, we are sure to see more sophisticated applications of remote sensing applications in crops, which we already see in the current years as well, where countries like Nepal deserve those being applied as well.

REFERENCES

Corvino, G., Lessio, A., & Borgogno-Mondino, E. (2018). Monitoring Rice Crops in Piemonte (Italy): Towards an Operational Service Based on Free Satellite Data. *IGARSS 2018 - 2018 IEEE International Geoscience and Remote Sensing Symposium*, 9070–9073. https://doi.org/10.1109/IGARSS.2018.8518634

DDNS. (2016). *Monitoring of rice crop using satellite Remote Sensing and GIS technologies in Afghanistan*. FAO. https://www.fao.org/publications/card/en/c/880bb443-03de-4de6-bb61-05dab770d5e8/

Dong, J., & Xiao, X. (2016). Evolution of regional to global paddy rice mapping methods: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, *119*, 214–227. https://doi.org/10.1016/j.isprsjprs.2016.05.010

Gao, F. (2021). Remote Sensing for Agriculture. In L. Di & B. Üstündağ (Eds.), *Agro-geoinformatics: Theory and Practice* (pp. 7–24). Springer International Publishing. https://doi.org/10.1007/978-3-030-66387-2_2

Hatfield, J. L., Cryder, M., & Basso, B. (2020). Remote Sensing: Advancing the Science and the Applications to Transform Agriculture. *IT Professional*, *22*(3), 42–45. https://doi.org/10.1109/MITP.2020.2986102

Johnson, G. E., Gurung, H., & Willard, M. (1984). *Agricultural Resources Inventory Project Mid-Term Evaluation Report*. https://pdf.usaid.gov/pdf_docs/PDAAP548.pdf

Juwa, G. B. (2009, September 1). Application of Remote Sensing and Geographical Information System (GIS) in forest survey in Nepal. *Geospatial World*. https://www.geospatialworld.net/article/application-of-remote-sensing-and-geographical-information-system-gis-in-forest-survey-in-nepal/

Kerr, J. T., & Ostrovsky, M. (2003). From space to species: Ecological applications for remote sensing. *Trends in Ecology & Evolution*, *18*(6), 299–305. https://doi.org/10.1016/S0169-5347(03)00071-5

Khanal, S., Kc, K., Fulton, J. P., Shearer, S., & Ozkan, E. (2020). Remote Sensing in Agriculture—Accomplishments, Limitations, and Opportunities. *Remote Sensing*, *12*(22), Article 22. https://doi.org/10.3390/rs12223783

Kuenzer, C., & Knauer, K. (2013). Remote sensing of rice crop areas. *International Journal of Remote Sensing*, *34*(6), 2101–2139. https://doi.org/10.1080/01431161.2012.738946

Kumar, S., Meena, R. S., Sheoran, S., Jangir, C. K., Jhariya, M. K., Banerjee, A., & Raj, A. (2022). Chapter 5—Remote sensing for agriculture and resource management. In M. K. Jhariya, R. S. Meena, A. Banerjee, & S. N. Meena (Eds.), *Natural Resources Conservation and Advances for Sustainability* (pp. 91–135). Elsevier. https://doi.org/10.1016/B978-0-12-822976-7.00012-0

Macdonald, R. B. (1984). A summary of the history of the development of automated remote sensing for agricultural applications. *IEEE Transactions on Geoscience and Remote Sensing*, *GE-22*(6), 473–482. https://doi.org/10.1109/TGRS.1984.6499157

Millette, T. L., Tuladhar, A. R., Kasperson, R. E., & Turner, B. (1995). The use and limits of remote sensing for analysing environmental and social change in the Himalayan Middle Mountains of Nepal. *Global Environmental Change*, *5*(4), 367–380. https://doi.org/10.1016/0959-3780(95)00071-U

Oli, P. P. (2002). *Accuracy and Application of Remote Sensing in Nepal*. Accuracy and Application of Remote Sensing in Nepal. https://a-a-r-s.org/proceeding/ACRS2002/Papers/EOS02-2.htm

Qamer, F. M., Shrestha, S., Shakya, K., Bajracharya, B., Shib, Shah, N., Regmi, R., Paudel, S., Shrestha, P., Paudel, S., Pokhrel, P., Di, L., Yu, Z., Cvetojevic, S., Guo, L., Mayer, T., Kruskopf, M., & Phalke, A. (2023). *Operational in-season rice*

area estimation through Earth observation data in Nepal Executive summary. https://doi.org/10.53055/ICIMOD.1017

SERVIR. (2014, December 5). *Agricultural officials trained at SERVIR-Himalaya*. SERVIR. https://servirglobal.net/Global/Articles/Article/1372/Agricultural-officials-trained-at-SERVIR-Himalaya

SERVIR. (2016, March 22). *ICIMOD uses NASA and USGS data to help Nepalese officials address severe drought*. SERVIR. https://servirglobal.net/Global/Articles/Article/1489/ICIMOD-uses-NASA-and-USGS-data-to-help-Nepalese-officials-address-severe-drought

Tiwari, V., Qamer, F. M., Matin, M. A., Ellenburg, W. L., Yousafi, W., & Kamal, M. (2021). In-Season Crop-Area Mapping for Wheat and Rice in Afghanistan and Bangladesh. In B. Bajracharya, R. B. Thapa, & M. A. Matin (Eds.), *Earth Observation Science and Applications for Risk Reduction and Enhanced Resilience in Hindu Kush Himalaya Region: A Decade of Experience from SERVIR* (pp. 79–101). Springer International Publishing. https://doi.org/10.1007/978-3-030-73569-2_5

Torre, D. M. G., Gao, J., & Macinnis-Ng, C. (2021). Remote sensing-based estimation of rice yields using various models: A critical review. *Geo-Spatial Information Science*, *24*(4), 580–603. https://doi.org/10.1080/10095020.2021.1936656

Torres, L. (2022, June 28). *Remote sensing as an effective solution for the development ...* https://www.planet.com/pulse/remote-sensing-as-an-effective-solution-for-the-development-of-the-rice-sector-in-uruguay/

USGS. (2022, January 27). *What is remote sensing and what is it used for? | U.S. Geological Survey*. What Is Remote Sensing and What Is It Used For? https://www.usgs.gov/faqs/what-remote-sensing-and-what-it-used

Xu, T., Wang, F., Yi, Q., Xie, L., & Yao, X. (2022). A Bibliometric and Visualized Analysis of Research Progress and Trends in Rice Remote Sensing over the Past 42 Years (1980–2021). *Remote Sensing*, *14*(15), Article 15. https://doi.org/10.3390/rs14153607