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Research Article

Crop Information System: Application of RS & GIS, A Case Study of Paddy Monitoring in Bharatpur 13, Nepal

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ABSTRACT

Rice as the main food in Nepal play an important role in food security. For planning purposes the information on rice is frequently required on large area and can be extracted from satellite images. Monitoring of crop growth and forecasting its yield well before harvested is very important for crop and food management. Remote sensing images are capable for identifying crop health as well as predicting its yield. Normalized Difference Vegetation Index (NDVI) calculated from remote sensing images has been widely used to monitor crop growth and relate to crop yield. This paper demonstrates an example on paddy monitoring using Sentinel 2 image for extracting NDVI at 5 days interval. A small area of rice cropland i.e. ward 13 of Bharatpur, Nepal has been selected as a case study for understanding NDVI during different phenological stages of rice crop with the land management factors. Google Earth Engine (GEE) cloud platform used in this study to extract NDVI of multiple sentinel images, as it reduces the space and time for data acquiring and processing. Using time series NDVI stacks, rice plant growth phases assessed with the land and management factors. Along with the rice monitoring, rice yield estimation is done using regression.

The result showed that there is significant correlation between NDVI and field level yield (r= 0.414 and r^2_{adj}=24.5%). The land and management factors and NDVI combination was accounted for 68.88% of the yield variability. Result indicates that NDVI stacks are invaluable to detect the cropping pattern throughout the time of surveillance. The factors that affect the yield and NDVI are not same.

Keywords: Time Series, Normalized Vegetation Index, Monitoring, Yield Estimation

Introduction

Rice is an important staple crop grown in Nepal. According to the MoALD 2018/19 report, rice accounts for nearly 70 % of the total arable land which is about 10% of area of Nepal. The average production of Nepal is 3.506 tons per hector. The average production of Nepal can be increased if proper monitoring and planning is carried out. Timely and reliable rice production monitoring and estimates are important in designing and monitoring government development plans related to food security in the region. Agriculture affects poverty alleviation and rural development process. Nepalese agriculture is facing one of the vital challenges of deceleration in agriculture growth. The reason for deceleration in agricultural growth is less investment in agricultural research and development. Proper application of precision agriculture technology can increase efficiency and profit in comparison to traditional framing practices. New technologies are needed to push out yield and utilize inputs more efficiently for sustainable and higher value cropping patterns. At the same time, it is necessary to exploit potential of rain-fed and other less endowed areas, if we are to meet the targets of agricultural growth and poverty alleviation. Future growth needs to be more rapid, more widely distributed and better targeted. These challenges have profound implications on the way farmers' problems are conceived, researched and transferred to the farmers. Agriculture research will increasingly be required to address location specific problems faced by the communities.

An early definition by Calkins and Tomlinson (1977) states "A geographic information system is an integrated software package specifically designed for use with geographic data that performs a comprehensive range of data handling tasks. These tasks include data input, storage, retrieval and output, in addition to a wide variety of descriptive and analytical processes." From the definition, it becomes clear that GIS handles geographic data, which include both spatial and attribute data that describe geographic features. Second basic functions of GIS include data input, storage, processing and output. It connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there). This provides a foundation for mapping and analysis that is used in science and almost every industry. It helps users understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision making. The most used GIS are Arc Map, QGIS, ERDAS, etc. The basic concept of GIS is one of location and spatial distribution and relationship.[4]

Monitoring vegetation is important to the entire environment because of the carbon stored in their biomass and the potential for carbon exchange between this one and the atmosphere. In the same way, understanding land-cover conversion and dynamics is one of the key research topics because changes in land surface, water, energy, nutrient, and carbon cycle in a region and its surrounding ecosystems. Satellite imagery provides the large spatial and temporal scales necessary to address vegetation analysis in an appropriate way. Numerous remote sensing studies have been involved in the mapping and analysis of relative vegetation cover at various scales, utilizing indices based on optical spectral behavior of vegetation. Although optical remote sensing can be considered a relatively powerful mapping tool, there are recognized limitations of these data due to cloud interference, atmospheric attenuation and some constraints in its use for vegetation discrimination.[3]

Vegetation Indices (VIs) are robust empirical measures of vegetation activity at the land surface. They are designed to enhance the vegetation signal from measured spectral responses by combining two (or more) different wavebands, often in the red (0.6-0.7 m) and NIR wavelengths (0.7-1.1 m), and are widely used in the studies of crop land classification, yield prediction, phenology, and crop growth monitoring.[14] The Normalized Difference Vegetation Index (NDVI) is by far the most widely used index in the literature, and is advantageous for studying historical changes; however, it is sensitive to canopy background variations and saturates in relatively high-vegetated areas.[5] Reliable and timely monitoring and mapping of rice is of global importance.[13] Mapping of paddy crop helps in the estimation of water supply required for irrigation, net production and yield estimation.[11] Monitoring of paddy crop in a country also aids in assessing the national food security, for planning and sustainable management of available resources.[6]

Crop yield estimation in many countries is based on conventional techniques of data collection for crop and yield estimation based on ground-based field visits and reports. Such reports are often subjective, costly, time-consuming and prone to large errors due to incomplete ground observation, leading to poor crop yield assessment and crop area estimations.[10] In most countries, the data become available too late for the appropriate actions to be taken for averting food shortage.[12,9] Satellite remote sensing has been widely applied and is recognized as a powerful and effective tool for identifying agriculture crops.[8] An important goal of agricultural remote sensing research is to spectrally estimate crop variables related to crop conditions, which can subsequently be entered into crop simulation and yield models.[1] To utilize the full potential of remote sensing for the assessment of crop conditions and yield prediction, it is essential to quantify the relationships between the agronomic parameters and spectral properties of the crop.[7] Use of satellite spectral data for the estimation of crop yields is an attractive prospect because yield is related to crop vigor, is related with its spectral response which in turn also related to the spectral response of the crop measured by satellite sensors.[2] There are reports of various studies on the suitability of satellite data for estimating crop yields. The correlation between the spectral reflectance of crops and agronomic variables has encouraged the application of these data in crop yield models.[1]

Phonological Stages of Rice

Rice plants take around 3-6 months to grow from seeds to mature plants, depending on the variety and environmental conditions. They undergo three general growth phases: vegetative, reproductive, and ripening. Rice varieties can be categorized into two groups: the short-duration varieties which mature in 105-120 days and the long-duration varieties which mature in 150 days. A 120-day variety, when planted in a tropical environment, spends about 60 days in the vegetative phase, 30 days in the reproductive phase, and 30 days in the ripening phase.

Germination

Germination in rice occurs when the first shoots and roots start to emerge from the seed and the rice plant begins to grow. To germinate, rice seeds need to absorb a certain amount of water and be exposed to a temperature range of 10-40 °C. This breaks the dormancy stage of the seed. When planted into flooded soil, the shoot is the first to emerge from the seed, with the roots developing when the first shoot has reached the air. If the seed is planted in non-flooded soil, the root is the first to emerge from the seed and then the shoot.

Vegetative Phase

The vegetative phase is characterized by the development of tillers and more leaves, and a gradual increase in plant height. The number of days the vegetative stage takes varies depending on the variety of rice, but is typically between 55 and 85 days. The early vegetative phase begins as soon as the seed germinates into a seedling and ends at tilling. The seedling stage starts right after the first root and shoot emerge, and lasts until just before the first tiller appears. During this stage, seminal roots and up to five leaves develop. As the seedling continues to grow, two more leaves develop. Leaves continue to develop at the rate of one every 3-4 days during the early stage.

The late vegetative phase starts when tilling begins, which extends from the appearance of the first tiller until the maximum number of tillers is reached. This typically happens 40 days after sowing. The stem begins to lengthen late in the tilling stage and stops growing in height just before panicle initiation about 52 days after sowing, which also signals the end of the vegetative phase.

Reproductive Phase

The first sign that the rice plant is getting ready to enter its reproductive phase is a bulging of the leaf stem that conceals the developing panicle, called the ‘booting’ stage. Then the tip of the developing panicle emerges from the stem and continues to grow. Rice is said to be at the ‘heading’ stage when the panicle is fully visible. Flowering begins a day after heading has completed. As the flowers open they shed their pollen on each other so that pollination can occur. Flowering can continue for about 7 days.

Ripening Phase

The ripening phase starts at flowering and ends when the rain is mature and ready to be harvested. This stage usually takes 30 days. Rainy days or low temperatures may lengthen the ripening phase, while sunny and warm days may shorten it. The last three stages of growth make up the ripening phase.

Ripening follows fertilization and can be subdivided into milky, dough, yellow, ripe, and maturity stages. These terms are primarily based on the texture and color of the growing grains. The length of ripening varies among varieties from about 15 to 40 days. Ripening is also affected by temperature, with a range from about 30 days in the tropics to 65 days in cool temperate regions.

Objectives

Primary Objectives

The essential objectives of this study is to monitor the different phenological stages of paddy using time series NDVI with the land and management factors at field level.

Secondary objectives

a. To develop the model for estimation of paddy production
b. To assess the gap between potential and actual field
c. To assess the possibility of using single date multi-spectral image for yield production

Study Area

The study was conducted in Bharatpur Metropolitan City area in chitwan district of Gandaki Pardesh in Nepal. It consists of 29 wards covering 433 sq. km and bordered by Narayani River and Rapti River. Among 29 wards, the study area is ward no. 13 of Bharatpur Metropolitan City covering an area of 9.688 sq km. It lies in 27˚34’23”N, 84˚22’48”E. It is surrounded by Rapti river in the south, ward 8 in the east, ward 6 in the north and ward 22 & 14 in the west. The population of Bharatpur municipality is 199,867(census 2011) out of which 5973 people lives in our study area.

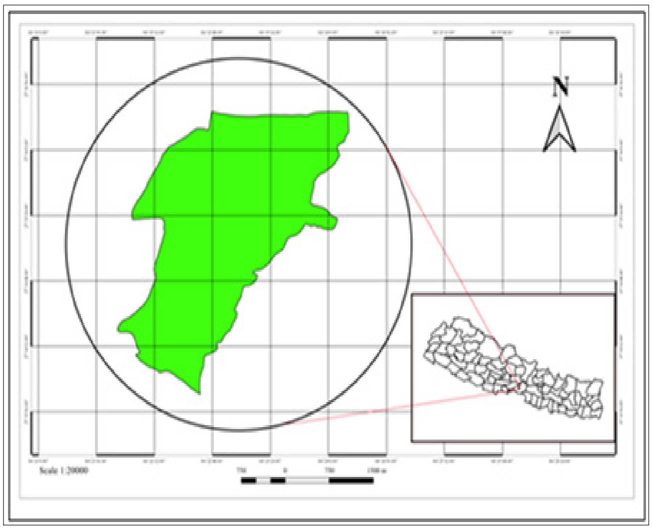


Figure 1.Study Area

The area is located in the central climatic zone, where monsoon starts in mid-June and eases off in late September. During these 14–15 weeks most of the 2,000 mm yearly precipitation falls – it is pouring with rain. After mid-October the monsoon clouds have retreated, humidity drops off, and the top daily temperature gradually subsides from 36°C / 96.8 °F to 18°C / 64.4 °F. Nights are cooling down to 5°C / 41.0 °F until late December, when it usually rains softly for a few days. Then temperatures are rising gradually.

Methodology

Data and Software Used:

For this study, series of sentinel images of 10m spatial resolution taken between the dates 14 July to 28 November of 2018 was used in a Google Earth Engine environment and QGIS 3.4. The data on management of paddy and its yield was taken from the farmers interviews. The garmin GPS map 62s device used to trace the field and kobo collect to collect the data from farmer interviews. The Power BI Desktop and Excel were used for data analysis and visualization.

Data Collection

Primary data on land and management for paddy for the season July to November 2018 was collected from the farmers through interviews. The interviews were conducted on farmers' field. A checklist was used to get familiar with the study are and to pre-test the checklist. Farmer/ field selection was purely random but it is based on the availability of farmers. The field was digitized using a hand held GPS with an accuracy about 4m. A total of 31 farmers were interviewed and their fields were digitized.

Data Preparation & Analysis

The data extracted from the images and collected from the farmers were entered into excel. Interview data was coded and standardized. The field polygons from the hand held GPS were extracted into a laptop and processed to create a database. The following follow chart of figure 8 is illustrating a summary of the procedure for data collection and analysis.

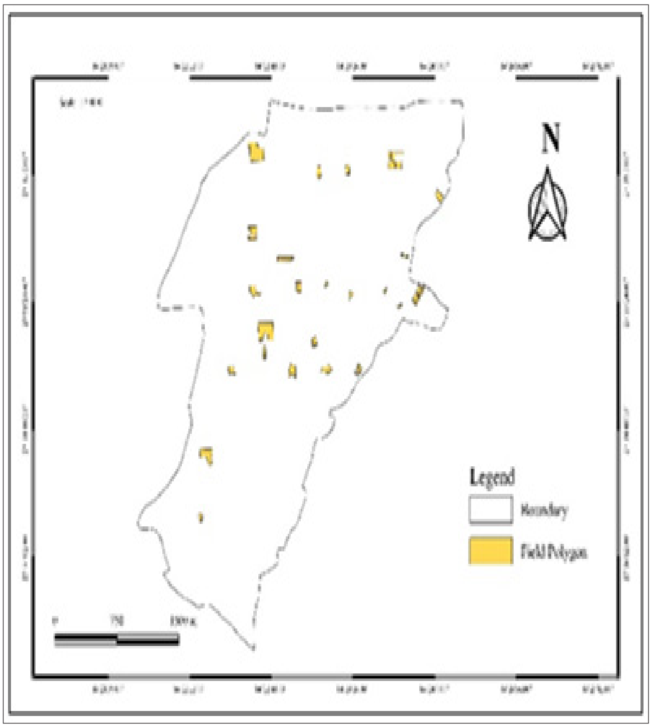


Figure 3.Field Polygon

Figure 4.Study Area Sentinel Image of Date 2018/10/02

Figure 5.Handheld GPS

Figure 6.Field Digitizing with Handheld GPS

Results

Monitoring and Analysis of NDVI with Yield

Data on land and management practices to grow rice during monsoon season 2018 and the respective yield data were collected from farmers through interviews. Data units as reported by farmers were converted into standard metric (S.I.) units. The sentinel 2, satellite image of five days interval has provided the field level NDVI data. The total sample size for this study consisted of 31 valid fields. The terms used as minimum, median and maximum NDVI are the maximum value of NDVI during its life cycle when NDVI over field is extracted at minimum, median and maximum NDVI at different dates.

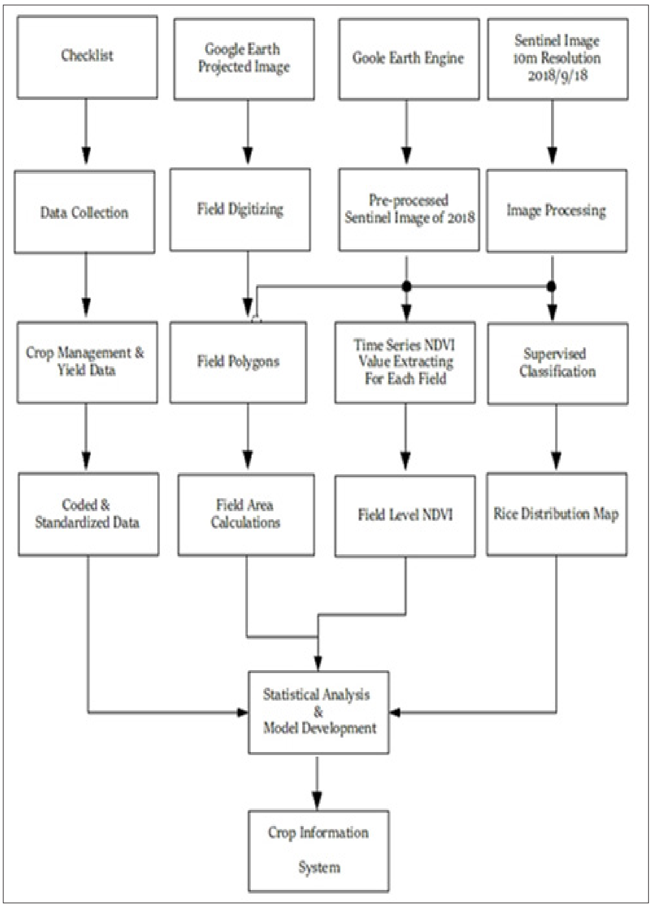


Figure 8.Flow Chart for the Data Method and Data Analysis

NDVI and Field Level Yield Data

The NDVI calculated from the sentinel 2 images using Google earth engine, maximum NDVI of maximum, median and minimum NDVI of the field calculated over different dates during the life cycle of paddy were obtained for each field. The NDVI were then correlated to the yield data and it was found that maximum, median and minimum NDVI were significantly correlated to yield with correlation coefficients of r = 0.315, r =0.413and r = 0.282, for maximum, median and minimum NDVI respectively.

The linear regression between maximum, median and minimum NDVI with yield is computed. The result suggested that there is a significant relationship between yield and maximum NDVI (r^2_{adj} =0.165), median NDVI(r^2_{adj} =0.245) and minimum (r^2_{adj} =0.164). From the r square adjusted value, maximum and minimum NDVI have similar range of output, but medium value is proved to be better for the explanatory of the three. The result linear regression equation between yield and median NDVI is as follow.

Yield = -5714.0555+15858.997*(median NDVI)

r^2_{adj}=24.5%

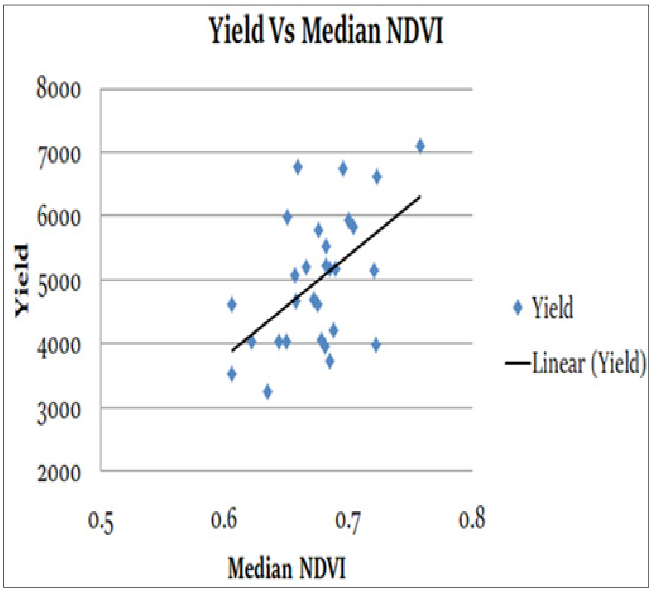


Figure 9.Yield Vs Median NDVI Chart

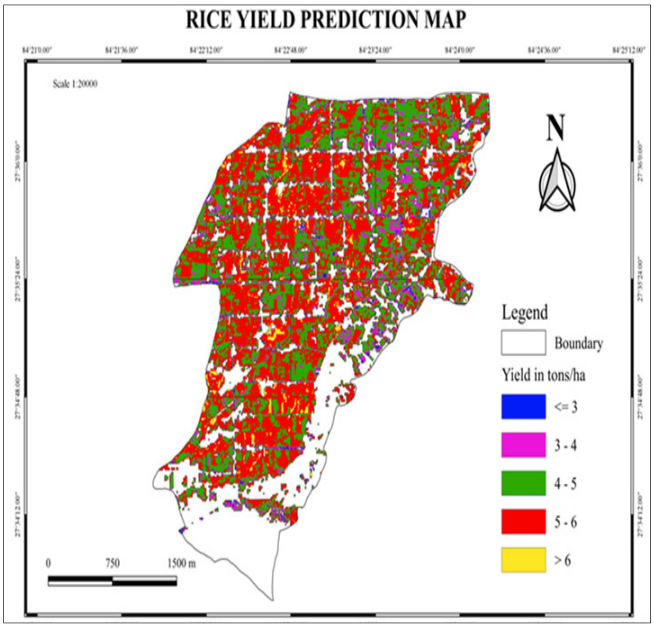


Figure 10.Yield Prediction Map using NDVI from Sentinel 2 Image of Date 2019/10/02

NDVI and Phonological Stages at Different Dates

Generally, paddy growth phase is divided into vegetative and generative phase. Vegetative phase is further segmented into four growth stages, i.e. germination, seedling, tilling, and stem elongation. Vegetative phase is the longest phase in paddy's life cycle, about 55-85 days. Generative phase consists of reproductive and ripening. Reproductive phase begin with panicle initiation to booting stage, heading, and flowering. Ripening phase begins with milk grain stage, dough grain stage, and ends with mature grain phase. Reproductive and ripening phase is about 30 days and 15-40 days respectively.

From the figure 11, during vegetative phase the minimum NDVI values goes to negative and maximum NDVI is positive. The reason behind the negative NDVI is due to presence of cloud in the atmosphere and presence of water in the field. During the vegetative phase, number of leaf on paddy raises, also the number of tillers and stems elongate which all cause increasing vegetation index. The minimum NDVI line shows the minimum NDVI value, median NDVI line shows the median NDVI value, maximum NDVI line shows the maximum NDVI value shown by paddy at each dates. When the flowering stage of reproductive stage starts the NDVI increases rapidly to maximum and the reproductive phase is about 30 days long. Paddy leaves start yellowing along the ripening phase, and remaining chlorophyll is low. This implies that vegetation index also decreases. Figure 12 shows the average time series NDVI with respect to dates.

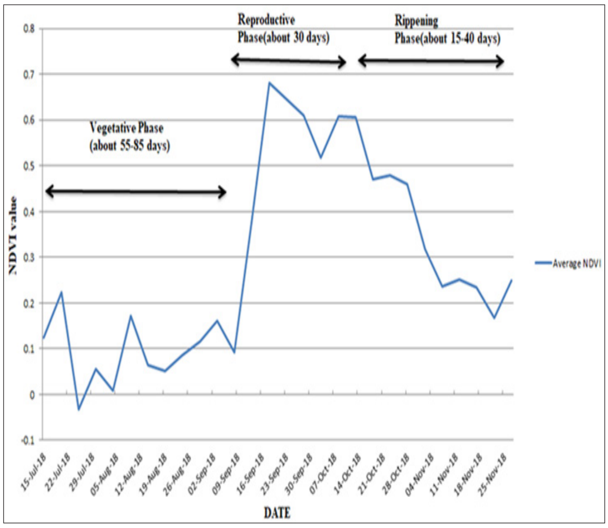
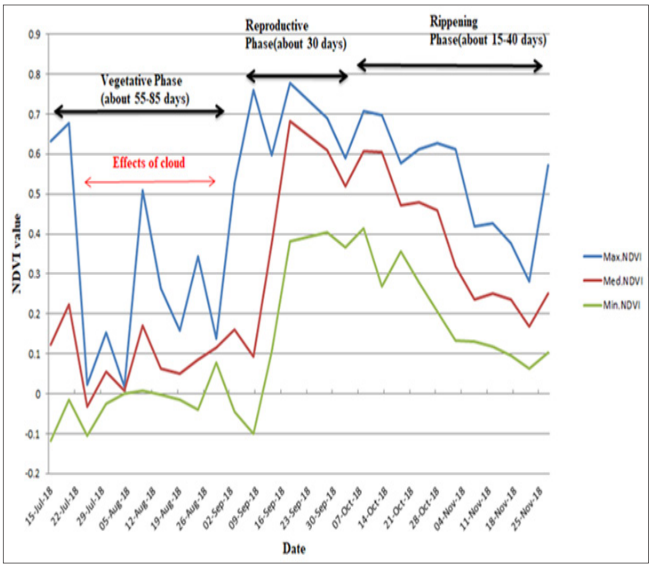


Figure 12.Time Series Chart Showing the Average of Minimum, Median and Maximum NDVI at Different Dates



The effect of Land Parameters on Yield and NDVI

Relationship between Yield, NDVI and Soil Groups

Soil is a very important component of dynamic ecosystem that nurtures healthy plants. It is a medium for water and nutrient supply to crops. Its natural characteristics determine the availability and supply of these resources to the crop.

Table 1.Table Showing the NDVI and Yield at Different Soil Type

Soil Type	Count	Max NDVI	NDVI	Average Yield(kg/ha)
A1	18	0.74	0.6817	4936.37
B2	9	0.725	0.6831	5097.22
C3	3	0.722	0.6643	4748.44
D4	1	0.70	0.61	3522.42

In the table A1, type of soil is called ‘Kalo Mato’, B2 as ‘Balaute’ C3 as Rato Mato and D4 as ‘chimtailo’ in local language. From the above table of data collected from the field and remote sensing, we can say that most of the area of study area has soil type A1 and have average yield of 4936.37kg/ha. The soil type B2 has average maximum yield of 5097.22kg/ha and NDVI of 0.6831. It means that A1 and B2 type of soil is very favorable for paddy production. In the graph NDVI vs Soil Type as the difference between maximum and median NDVI increases the production is less. This means that as the maximum NDVI and median NDVI is closer, the better will be the production. The D4 soil type has low production. In the NDVI time series figure 14, the NDVI pattern of rice grown in D4 soil type is fluctuating randomly.

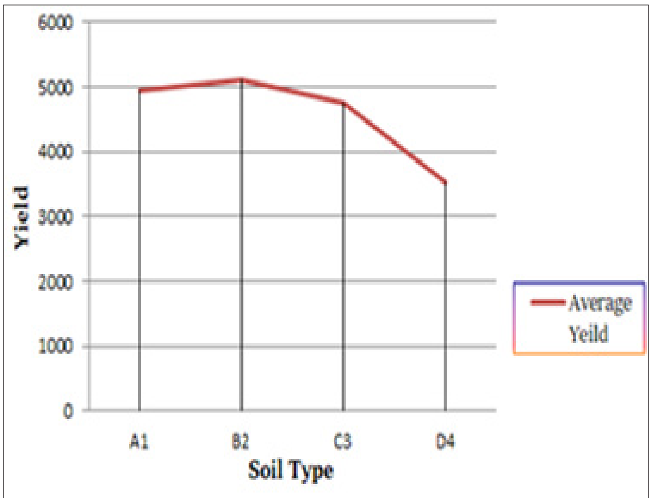


Figure 13.Chart Showing Yield in different Soil Type

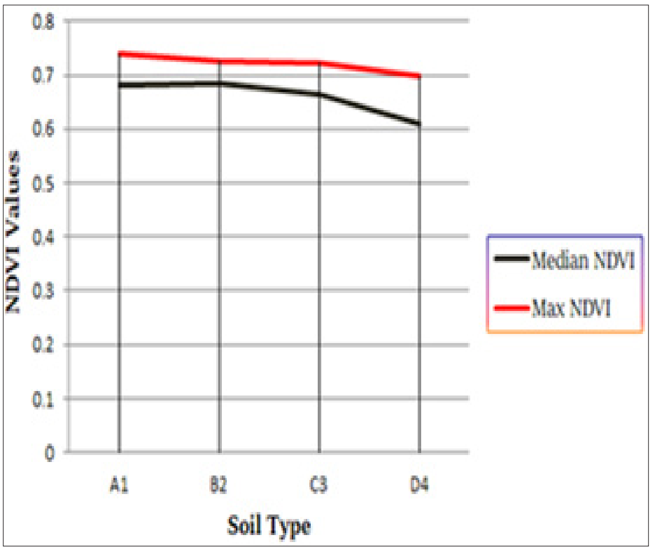


Figure 14.Chart Showing NDVI at Different Soil Type

From this behavior of NDVI, we can conclude that the health of paddy is low as NDVI decreases. The low health of paddy is the result of problems due to attack of pest and diseases or due to lack of sufficient nutrients. When farmer cure the problem, again the NDVI is increasing. This has affected in the average paddy yield.

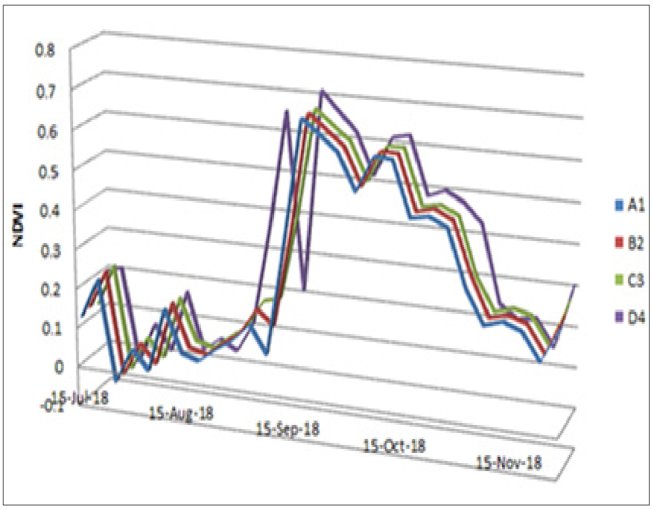


Figure 15.3D Chart Showing Time Series NDVI of Different Soil Type

Varieties Grown

Nowadays people use the hybrid and high productive paddy seed from authorized distribution center. This trend has improved the productivity of rice. There are about 16 different varieties of paddy grown in Chitwan district. But in the study area, the following different varieties samples were found.

From the table 2, it is clear that sabitri is the most widely grown varieties having the average yield of 5017.677kg/ha. The average yield of 4 tons per hector is considered as the good yield. Though the NDVI value of hardinath varieties is higher, it has low production. On plotting the time series NDVI of hardinath with average NDVI of all reported field and sabitri, sabitri follows the similar NDVI pattern with average NDVI but hardinath have fluctuating NDVI pattern. The fluctuating NDVI nature represents the change in crop health. Due to the fluctuating nature of NDVI, on having the high NDVI, the production is not satisfactory in compared to other varieties.

Using the rice variety field polygon, supervised is carried out on sentinel image of date 2018/10/02, following distribution was obtained.

Table 2.Table Showing Average Yield and NDVI of Different Varieties of Rice

Varieties	Count	Yield(kg/ha)	Max NDVI	Med. NDVI	Growing period (days)
Sabitri	20	5017.677	0.732	0.676	140
Sama	3	5124.167	0.743	0.706	120
War	2	4564.395	0.725	0.685	-
Sona Masuli	4	4633.265	0.72	0.637	-
Hardinath	2	4554.77	0.753	0.721	-

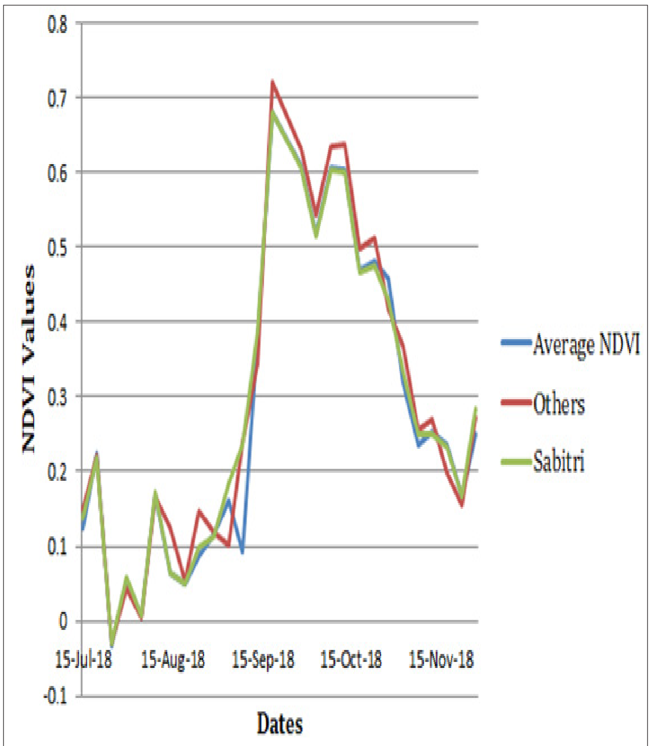


Figure 16.Chart Showing Time Series NDVI of Sabitri and Other Varieties of Rice

Table 3.Table Showing the Result Obtained from Rice Distribution Map

Name	Total % of land covered	Area in ha
Sabitri	36.67	355.91
War	7.69	74.63
Sona Mansuli	8.98	87.21
Sama	8.05	78.17
Others	11.12	110.98
Total	72.51	703.9

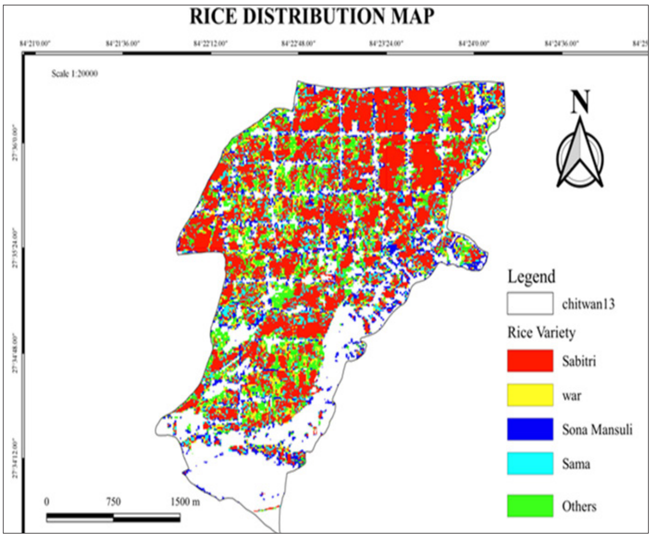


Figure 17.Rice Distribution Map

Ploughing

In traditional method of farming, people used animals and tools called plough for ploughing the field. This trend has been changed. Nowadays people use tractors for ploughing the field. This practice is fast and better than traditional practices.

Ploughing starts from early Jestha(May/June) month. 3 Farmer did first plough in bhaishak, 9 farmer in jestha, 15 farmer in asar and 4 farmers in shrawan. All the farmers plough 2 times but only 17 farmers plough 3 times. From the correlation between the Yields, max, NDVI and ploughing following table is obtained.

Table 4.Correlation of Ploughing with Yield and NDVI

Correlation	Yield	NDVI
Ploughing	0.1130	0.000837

From the table 4, the r value between Ploughing and Yield (r=0.1130) and NDVI (r=0.000837) both are positive. It means the yield and NDVI can be high as the number of Ploughing is increased. But the strength of correlation is low, which mean only very small increase in production can be achieved.

Date of Transplantation

Paddy rice is mainly transplanted when the seedlings are about 30 days old; sowing was mostly done in Transplanting dates ranged from as early as 25th asar to 20th shrawan 2018. with most farmers transplanting in the 80 to 120th day of the year as shown in the figure 18.

Transplanting time in each field is depended on the availability of labor. Most of the transplanting was done within one day (by hand). In the regression test, transplanting date has no significant effect on yield.

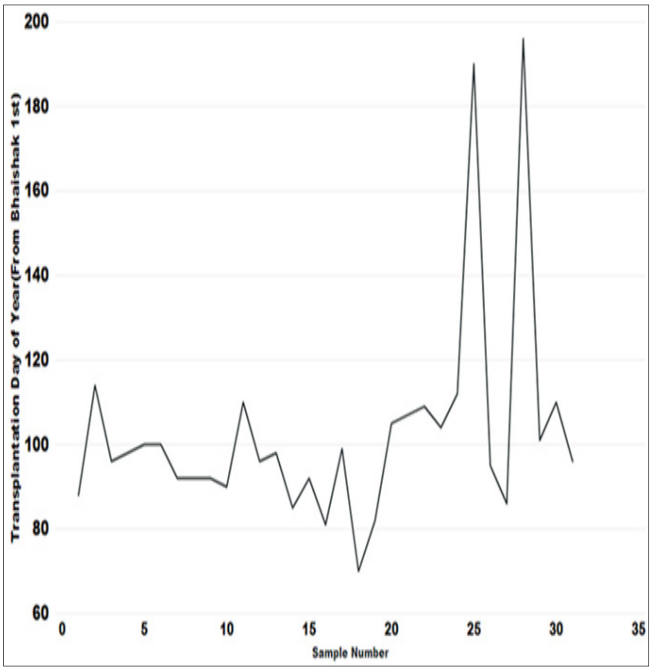


Figure 18.Chart Showing Transplantation Day of the Year for a Sample no.

Table 5.Table Showing Average Yield and NDVI at Land Type

Land Type	Count	Average Yield(kg/ha)	NDVI
Ghol	9	5142.081	0.6747
Tadi	21	4814.171	0.6796

Land Type

Basically, there are two types of land type in the study area. In local language the land type is called as 'ghol' and 'tadi'. The land type is classified according to their level of height. The low height land is called ghol and land having height slightly higher than ghol are called tadi.

From the table 5, it is clear that the ghol type of land has better yield than tadi type of land. Tadi has least yield, resulting an average yield 4814.171 kg/ha and NDVI of 0.6796 while ghol has high yield of 5142.081 kg/ha with NDVI of 0.6796. Tadi land type has relatively low production than that of ghol type. In this analysis, even the NDVI of ghol type paddy is low than that of tadi paddy, the yield is better than that of tadi. In the figure 19, the ghol type and tadi type of land follows similar NDVI patterns, but ghol type land paddy have higher NDVI in some dates. In the field visit, we find that the organic manure, fertilizers and other minerals get into the ghol land from nearby during heavy rainfall because of its relatively low height than that of tadi land. Also farmer used to grow different varieties of paddy in ghol and tadi type of land. This can be the reason behind the better production than that of paddy at tadi.

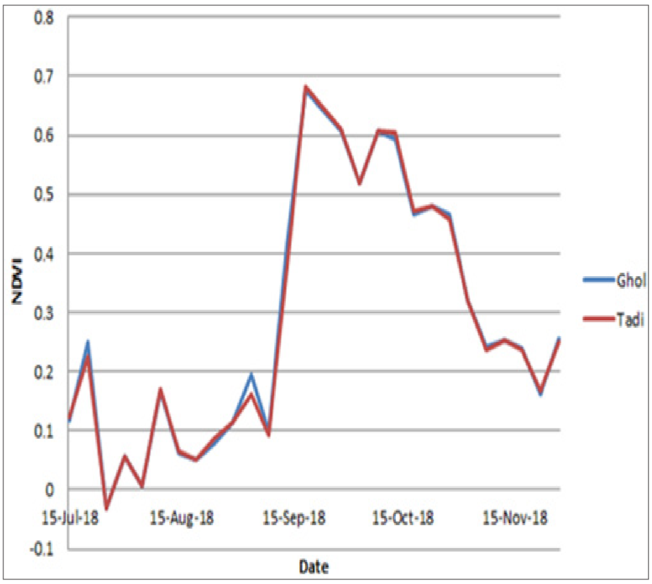


Figure 19.Time Series NDVI of Land Type

Irrigation

Irrigation is very important for the paddy crop. Paddy crop needs relatively high amount of water than that of other crops. From the field observation, the regular irrigation has been a problem in the tadi area. Farmers are using the motor for the irrigation and some field are provided with the canal irrigation.

Table 6.Table Showing the NDVI and Yield at Different Types of Irrigation Availability

Irrigation	Count	Average Yield(kg/ha)	Max NDVI	Med. NDVI
Regular	17	4897.59	0.7429	0.682
Shortage	14	4945.60	0.7192	0.672

In the table 6, shortage in irrigation means irregular supply/available of water during the reproductive phase of the paddy life cycle period. Regular irrigation means regular supply/available of water throughout the paddy life cycle period and especially in reproductive phase. From the table, it is concluded that regular irrigation area has relatively low amount of production than that of irrigation shortage area. The average NDVI of irrigation shortage area (0.7429) have high NDVI than that of regular irrigation area (0.7192).

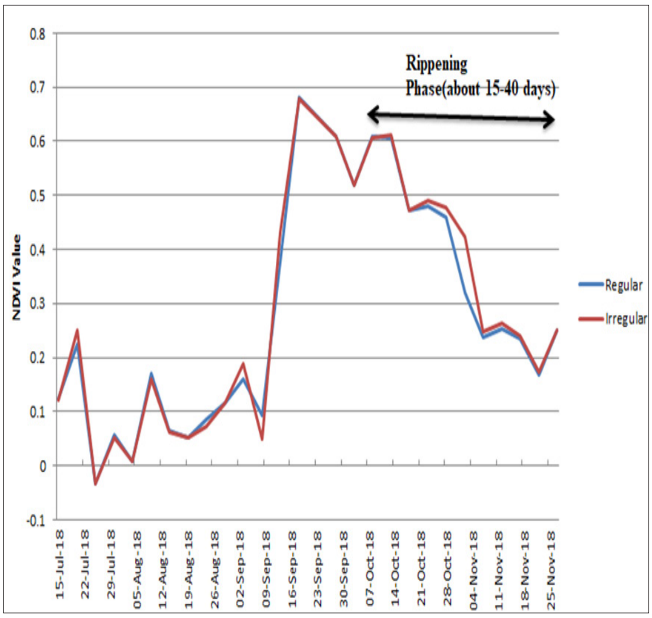


Figure 20.Time Series NDVI of Irrigation Availability

Amount of Seed Growth

The average amount of seed used to crop hector area varies according to farmer. They used seed according to their perception of how densely they will cultivate and how good will be seedlings.

The Pearson r correlation coefficient between amount of seed growth and yield is r= 0.311 which is positive relationship. In the analysis of correlation, it is considered that correlations above 0.4 to be relatively strong; correlations between 0.2 and 0.4 are moderate, and those below 0.2 are considered weak. Thus, relationship between amount of seed and yield can be said as moderate relationship.

Damage Due to Pest and Diseases

In the crop production, pest and diseases can be very harmful in production. So, the crop should be regularly checked and monitored. The main pest that are found in during paddy growth are gall mudge (local name:dhungre kira), leaf folder(local name: pat berne), brown plant hopper (local name: khaira fadke kira), stem borer (local name:gawaro kira) etc. All these types of pest can be easily controlled using pesticides on the consulting with experts. The main types of diseases that are found on paddy are blast (local name: blast), bacterial leaf blight (local name: daduwa rog), false smut (local name:kalo poke), sheath blight etc.

Table 7.Table Showing Average Yield and NDVI at the Field Damage due to Pest

Damage due to Pest	Count	Average Yield(kg/ha)	Max NDVI	Med. NDVI
High Damage	0	0	0	0
Medium Damage	8	4265.38	0.736	0.667
No Damage	23	5146.711	0.732	0.681

Damage due to insects and diseases has been categorized into hard damage, medium damage and no damage.

In the table 7, the average yield on medium damage area due to pest is nearly 1 ton less than that of no damage area. The maximum NDVI is in medium damage is high than no damage area. But looking at the median NDVI, it is low than that of no damage area. This means that the maximum NDVI represent the maximum NDVI shown by the crop and average median NDVI represent the overall value of NDVI over the field. When the crop is attacked by the pest, then its health wills deteriorates which has affected the median NDVI of the field.

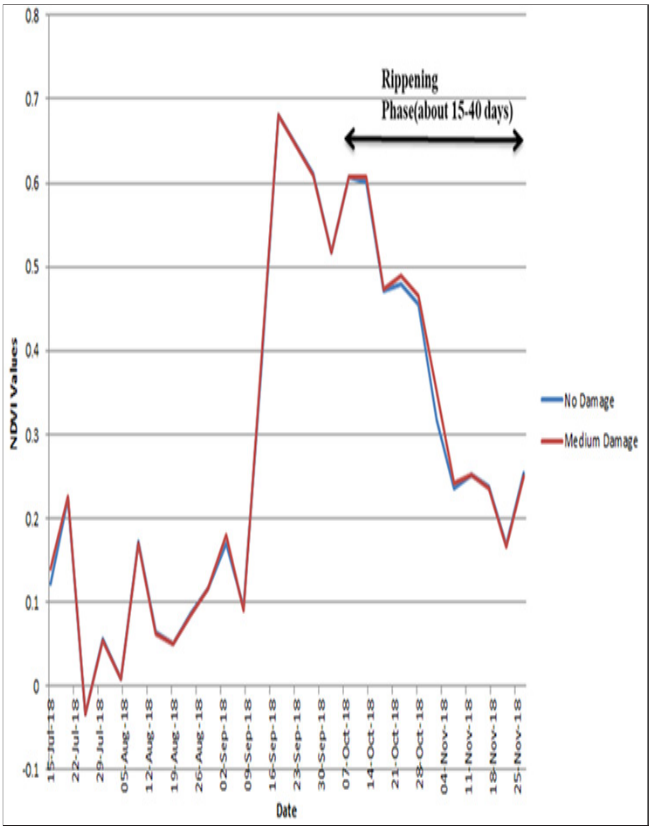


Figure 21.Chart Showing Time Series NDVI Value of the Field Damage by Pest

Table 8.Table Showing Average Yield and NDVI at the Field Damage Due to Diseases

Damage Due to Diseases	Count	Average Yield(kg/ha)	Max. NDVI	Med. NDVI	Difference (Max NDVI-Med. NDVI)
High Damage	2	3548.075	0.724	0.659	0.065
Medium Damage	3	4007.95	0.755	0.699	0.056
No Damage	26	5253.75	0.73	0.677	0.053

In the table 8, high damage due to diseases has very less yield i.e.3548.075kg/ha, medium damage have yield of 4007.97kg/ha and no damage area has high yield of 5253.75kg/ha. In this data, the high damage area has about 1.7 tons less production and medium damage area has about 1.2 ton of less production than that of the no damage area. Also the difference between maximum and median NDVI is high than that of no damage area in medium and high damage area. From this we can conclude that the diseases in the paddy are very harmful for the farmer. The crop should be regularly monitored so that the diseases can be cured in its early stage.

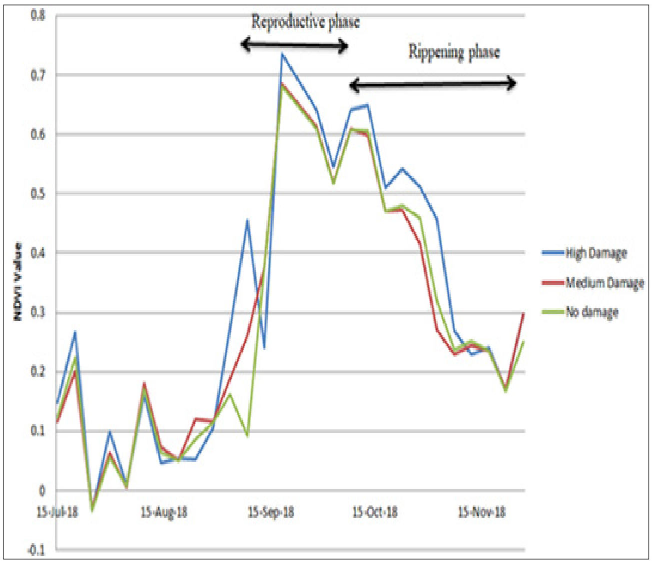


Figure 22.Time Series NDVI Chart of Damage by Disease Field

In fugure 22, on plotting the time series NDVI values of high damage, medium damage and no damage area at different dates, high damage field have high fluctuating series than medium and no damage field. From this study the difference of maximum and medium NDVI greater than 0.060 can be concluded to have greater risk of having problem of diseases.

Weeding

Weeding is an important control method practice in many crops. The removal of weeds is useful because these unwanted plants compete with the crop for space, water and nutrients. Weed control should usually be done in an early crop stage, as this is more practical (the weed plants are smaller) and more effective.

In the study area, the entire farmer use hand weeding method for weeding. Only 3 farmers have done weeding 2 times, 29 farmers have done weeding only 1 time. Our data is not sufficient to explain how much the 2 times weeding can help to yield better.

Table 9.Table Showing the Maximum NDVI and Yield at Different Days Interval of Year

Days of the Year (from Bhaishak 1st)	Count	Average Yield	MAX NDVI
185-195	5	4508.364	0.712
196-205	10	4904.686	0.739
206-215	14	5257.752	0.740
216-225	1	3257.28	0.68
226-235	1	4042.91	0.70

Date of Harvesting

The date of harvesting in the study area ranges from 2nd of kartik to 2nd week mangsir.

From the table 9, most of the farmer has harvested during the period of 206-215 days of the year from bhaishak 1st with an average yield of 5627.177 and NDVI of 0.740 which is the maximum value in comparable with the other interval. From this, it is clear that the 206-215 days of the year is best for harvesting paddy in the study area.

From the Pearson's correlation coefficient between the date of harvesting and yield we get r=0.0378 which is the low positive relationship. It means the increasing the date of harvesting will have very less increase in yield.

Fertilizers

Fertilizer natural or artificial substance containing the chemical elements that improve growth and productiveness of plants. Fertilizers enhance the natural fertility of the soil or replace the chemical elements taken from the soil by previous crops. Most of the farmer has used chemical fertilizers according to the organic manure they had used in the field. Those who have used large organic used organic manure in large amount have used the chemical fertilizers like urea and dap in the small amount than the prescribed amount.

Table 10.Table Showing Correlation and P-value of Fertilizers with Yield and NDVI

Fertilizers		Yield	NDVI
Organic Manure	P-value	0.0011	0.26
	Correlation	0.555	0.205
DAP	P-value	0.0066	0.044
	Correlation	0.477	0.364
Urea	P-value	0.60	0.74
	Correlation	-0.095	-0.062

Table 10, shows the p-value and correlation coefficient of organic manure, DAP and Urea with the yield and max NDVI. The organic manure and DAP has the p value less than 0.05 with yield, which means there is linear relationship between them. Also the p value between NDVI and DAP is lower than 0.05. It means the NDVI can be predicted when we know the amount of DAP used. On using linear regression between organic manure, dap with yield, we get the following equations:

Yield=3799.764+4.954158 x (organic manure/hector) with r^2_{adj}=28.44%

Yield=4382.358+13.06258 x (DAP,kg/ha) with r^2_{adj}= 20.13%

Summary of Relevant Finding

It is envisaged in this analysis that not all the parameters affecting yield and NDVI at field level have been exhausted. Factors like ground water level, basal dressing, top dressing, water quality (since irrigation depends on ground water in the area) etc. has not been explored to find its effect on yield and NDVI due to insufficient data available for this analysis.

In the analysis some parameters have been found to explain yield and NDVI variability.

Yield = f (NDVI, soil type, land type, irrigation, pest and diseases, fertilizers)

NDVI = f (soil type, variety, land type, irrigation, pest and diseases).

Model Development

Stepwise regression is a method of fitting regression models in which the choice of predictive variables is carried out by an automatic procedure. In each step, a variable is considered for addition to or subtraction from the set of explanatory variables based on some pre specified criterion. To develop the model for this study, stepwise backward regression was used. This method selects only those parameters that strongly and significantly explained yield variability. Repeated 'trial and error' attempts were done to identify interactions between parameters and to explore unexpected sign of coefficients. Right samples were randomly selected from the yield data and reserved for model testing. Multiple regressions were then applied to the remaining set of data.

Yield Prediction Model

All the significant variables were entered into the stepwise multiple regression to select the best subset that explains the field level NDVI variability. Through repeated trial and error, 2 variables were selected as predictors explaining 68.8%% (R2adj) of yield variability. The purpose of this was to identify which parameters can explain the yield variability to avoid auto correlation when building the final model. The regression equation is:

Yield = -2127.65+9114.54 (NDVI) - 964.895 (Land_tadi) + 691.544(Soil_A1) +5.388(OM) - 1140.06 (Dis_hard)

Where:

Yield = Predicted Yield (kg/ha)

NDVI =Field level NDVI aggregated by maximum

Land_tadi =If the land-type is tadi

Soil_A1 =If the soil type is A1

OM = Organic manure (doka/ha)

Dis_hard =If the damage by disease is hard damage.

This model suggest a negative effect on yield with tadi land-type and hard damage by disease. High yield will be obtained if paddy is grown in soil type A1 and if high amount of organic manure is applied.

Table 11.Yield Prediction Model using NDVI and Land Management Factors

Predictor	Coefficient	t	p
Constant= -2127.65	R^2_{ajj}=68.8%		
NDVI	9114.54	2.5	0.019
If land type is tadi	-964.895	-3.4	0.003
If Soil type is A1	691.522	2.7	0.014
Organic Manure	5.388	4.17	0.0006
If the damage by disease is hard damage	-1140.04	-2.27	0.036

In this model development, 23 samples data were used and remaining 8 samples were left for testing the model. Testing the model and plotting the reported yield on x-axis and predicted yield on y-axis, we got the regression line explaining the 56.75% (R^2) of the yield variability.

Table 12.Testing the Model for 8 Sample

S/N	Reported Yield(Y_R)	Predicted Yield(Y_P)	Difference(Y_R-Y_P)	% Difference(Y_R-Y_P)/Y_R X 100
1	5519.404	4491.177	1028.227	18.62
2	4042.908	3889.223	153.6858	3.8
3	3731.048	4540.769	-809.721	-21.7
4	6746.996	5636.364	1110.632	16.46
5	3972.112	5022.525	-1050.41	-26.47
6	5180.739	5865.609	-684.87	-13.21
7	4239	5886.841	-1647.84	-38.87
8	5933.39	4805.707	1127.683	19.005
Mean	4920.7	5017.277	-96.57	-5.292

Single Date Image for Yield Prediction

This study demonstrated that, single date image and field level yield can be predicted. The timing of the image to be used for yield estimation is important. Though the explained, good correlation between NDVI and yield. While using NDVI as an end-of- season yield estimator gives unsatisfactory results because of the problems of choosing the best time of the image to use. It is difficult to have a single date image representing on phenological stage at field level because of the difference in planting dates, varieties used. It is also very difficult to get a clear series of image due to presence of clouds. In this case a single date image can still provide good information to predict end-of-season yield as long as it is within the time when there is maximum vegetation (between panicle initiation and heading stage) and other production factors are taken into account. Crop ultimate growth is affected by its growth history and its land & management parameters. The yield can be predicted using NDVI and land & management parameters with the 65.88% variability should be realized that the predicted yield at any stage of plant growth account for all the factors that affect the crop from planting date to the time of prediction. This is then projected to the final yield. As such predicted yield reflects potential yield of the crop with the prevailing conditions. Factors such as drought, floods, pests and diseases happening after the prediction may significantly reduce the yields.

Conclusion

Open source earth observation data and cloud-based computing resources provide a remarkable advancement in the land-use land-cover mapping and in crop monitoring. By using the time series NDVI values chart, the different phenology phases of the paddy has been monitored and analyze with different land management factors. From field level NDVI, the health condition of the crops can be monitored. But the other indices like ratio based vegetation index, infrared percentage vegetation index, perpendicular vegetation index etc. should also be used for better monitoring which were not discussed in this study. It is found that the soil type, variety, land type, irrigation, pest and diseases can explain the NDVI variability.

Through integration of remotely sensed data, land factors and management aspects, an assessment of field level yield prediction has been executed. It is shown that a combination of NDVI, land and management parameters can improve field level yield prediction above use of NDVI alone. It is found that the NDVI, soil type, land type, pest and diseases, and fertilizers can explain yield variability. This study established that there is a significant positive relationship between Normalized Difference Vegetation Index and field level yield ($r=0.413$, $p<0.05$), where the production is the overall outcomes from the many factors acting on crop.

This study has developed a yield prediction model for field level. The data used in this study was provided by farmers through interviews. As such there might be a lot of anomalies in the reported data that has to be verified before final conclusions are drawn on its accuracy and applicability. There is need for further research to find more factors that can explain yield variability at field level and improve the model. Only a use of optical remote sensing cannot provide the best explanation in monitoring the crops. So, there should be integration of optical and microwave remote sensing for the advance level monitoring of crops.

The study has monitored phonological stages of paddy for the study area of Chitwan district and derived its growth metrics. This growth metrics can be very helpful to study the behavior of paddy in the study area. This study also developed a linear regression model to predict yield from NDVI, land and management factors. Regression model shows a good correlation (R^2_{adj} =24.5%) between NDVI and yield of paddy. Hence, we like to conclude that 5-days interval NDVI data from sentinel 2 can be successfully used to predict yield of paddy with fairly good accuracy.

The production in the study area ranges from 3257 kg/ha to 7100 kg/ha with average yield of 4919 kg/ha, median yield of 4691 kg/ha. In the study area, the total agriculture area about 700 ha with a capacity of producing the yield of 3443 ton of paddy during the study season. The population of study area is 5973.According to ministry of agriculture development data rice consumption per person is recorded at 87.75 kg per year in 2011-2013. Taking this into account the yield production of study area will feed about 39000 people. Which means it will feed about 33000 people outside from that area.

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