USE OF VEGETATION CONDITION INDEX FOR RICE YIELD FORECASTING

S.K. Dubey, Ashutosh Gavli#, S.K. Diwakar#, Neetu and S.S. Ray

Mahalanobis National Crop Forecast Centre, DAC&FW, Pusa Campus, New Delhi 110012
Randstad India Pvt Ltd, New Delhi, India
Email: sunil.dubey86@gov.in; shibendu.ncfc@nic.in

KEYWORDS- *Vegetation Condition Index, Rabi Rice, NDWI, Remote Sensing, Yield forecasting*

ABSTRACT: Rice is the staple food of country grown over the entire year. There are three main seasons for rice cultivation and they are named according to the seasons of harvest of the crop. *i.e* Autumn, *Kharif* or Winter and Boro or summer or Rabi. Major *Rabi* rice growing states are in the costal part of country *i.e.* Andhra Pradesh, Karnataka, Telangana, Odisha and West Bengal. They together consist of 9 per cent of total rice area. Accurate and timely forecasting of crop yield is a cornerstone for monitoring crop production and planning purpose, but the efficiency of the current system for near real-time forecasting may be improved by applying the remote sensing based approach. This study explored an approach for predicting the yield of *Rabi* rice using Vegetation Condition Index (VCI) derived from remote sensing data. Historic data of last 14-years (2003–2016) of NDVI (Normalized Difference Vegetation Index) and NDWI (Normalised Difference Wetness Index) were used to derive the VCI. MOD-13A2 series of MODIS instrument on-board Terra satellite at 16 days interval from first fortnight of November to second fortnight of March (10 fortnights) were used to calculate the NDVI & NDWI. District wise historical yield data was taken from DES. Study was carried out for 32 major Rabi Rice growing districts of Andhra Pradesh (6), Karnataka (4), Telangana (5), Odisha (8) and West Bengal (9). Stepwise regression technique were used to quantifying the relation between district wise VCI and historical yield. Strong relation (R^2) between the VCI and district wise DES yield was observed *i.e.* 0.45-0.97, 0.39-0.80, 0.70-0.95, 0.33-0.89, 0.25-0.70, for Andhra Pradesh, Karnataka, Odisha, Telangana and West Bengal, respectively. Except for 2 districts, the relationship was found to be statistically significant in all the districts. In 22 districts out of 32 districts, the relative deviation between DES yield and VCI estimated yield was lower than 10 per cent. Thus, this analysis showed that, in absence of weather soil and ground based observations (which are the major factors of crop production) the VCI can be used as a proxy variable for reliable yield estimation on operational basis.

1. INTRODUCTION

Early yield assessment at regional and national scales is becoming increasingly important to numerous user-groups e.g., agriculture planner, policy makers, crop insurance companies and researchers community (Dadhwal & Ray, 2000; Van Wart et al., 2013). It enables planners and decision makers to predict how much to import in case of shortfall or optionally, to export in case of surplus. Crop yield estimation in many countries is based on conventional techniques of data collection. Such techniques are often subjective, costly, time consuming and are prone to large errors due to incomplete ground observations, leading to poor crop yield assessment. Remotely sensed crop data offers considerable opportunities for agricultural decision makers via the possible improvement in crop yield predictions and crop loss assessment (Lobell 2013 & 2017).

In India crop forecasting using remote sensing data started in late 80s in Space Applications Centre of ISRO under the Department of Agriculture & Cooperation (DAC)'s sponsored project CAPE (Crop Acreage and Production Estimation). This later on developed into a national level programme, called FASAL (Forecasting Agriculture using Space, Agro-meteorology and Land based observations), which is operational since August, 2006. FASAL project aims at providing multiple pre-harvest production forecasts of crops at National/State/District level (Parihar and Oza, 2006). Due to increasing importance of remote sensing based crop forecasting a centre was created in 2012 called Mahalanobis National Crop Forecast Centre (MNCFC) under Ministry of Agriculture & Farmers Welfare (Ray et al., 2014). Under FASAL project, various approaches such as weather based, simulation model based and spectral model based yield estimation is being carried out forecast the crop yield.

Various studies have been conducted across the world to predict the rice yield using both optical (Son, *et al*. 2014) and microwave remote sensing data. VCI (Vegetation Condition Index) is an indicator of the vigour of the vegetation cover as a function of NDVI minima and maxima for a given land area. It normalizes NDVI according to its average over many years and results in a consistent index for different land cover types (Kogan 1990). If data are recorded over long periods during where extremes in climate are experienced, the VCI indicates potential of crop. VCI is considered the ideal index in Index based Insurance because it is highly correlated with crop yields and hence able to accurately track yield losses (Dubey, et al. 2016). In present study the effort has been made to evaluate the VCI for yield estimation of crops in Indian condition.

Rabi rice is commonly grown in costal part of country *i.e.* Andhra Pradesh, Karnataka, Telangana, Odisha and West Bengal during rabi season (sowing time November to February and harvesting time is March to June). During *Rabi* season rice crop is grown in few selected district of these states where residual moisture is sufficient to sustain the crop or proper irrigation facilities are available. In fact, NDVI-based Vegetation Condition Index (VCI) is considered to be a better indicator of crop than NDVI under in-sufficient moisture condition, as it reflects the vegetation vigour in comparison with the best and worst conditions over the same period in different years (Kogan 1990).

2. METHODS AND MATERIAL

Study was conducted in 32 major Rice growing districts *i.e.* Andhra Pradesh (6), Karnataka (4), Telangana (5), Odisha (8) and West Bengal (9), as depicted in **fig. 1.** In each state major Rice growing districts which has area more than 10000 ha area were selected for the study.

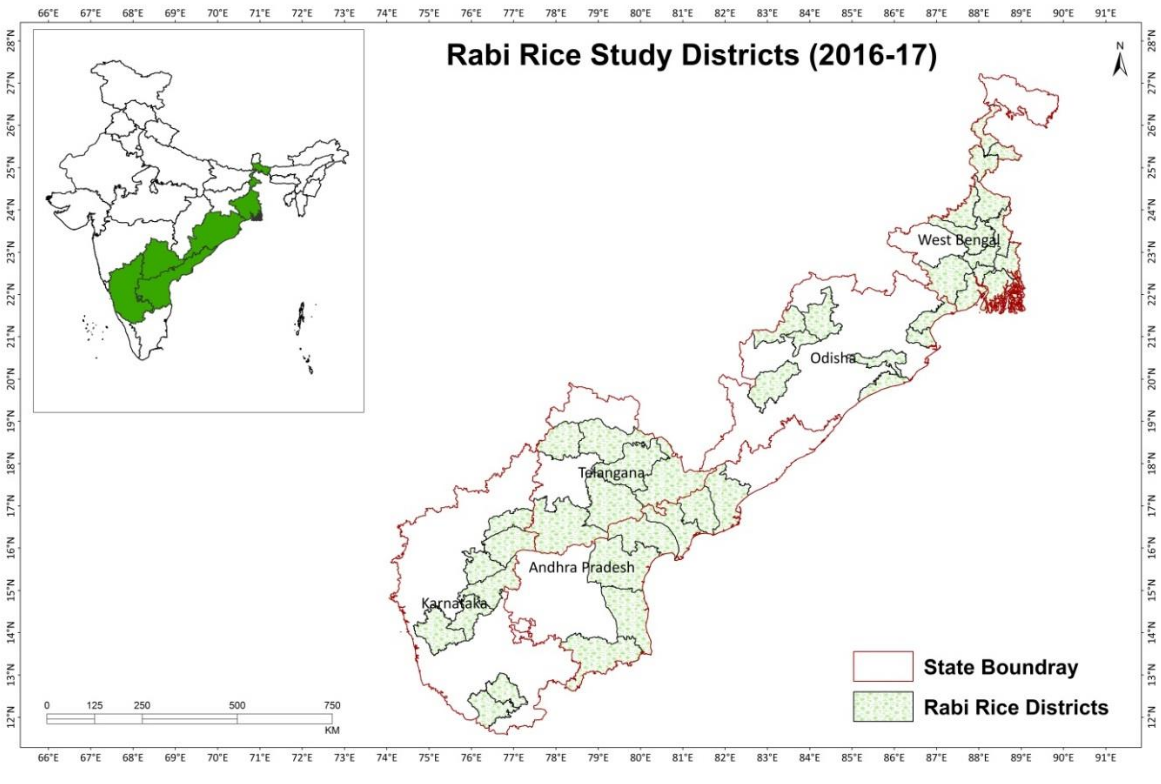

Figure 1: Study area

Global MODIS vegetation indices are designed to provide consistent spatial and temporal comparisons of vegetation conditions. In present study past 11-years (2006–2017) historical data of NDVI and NDWI has been used to derive the VCI. VCI can be defined as-

$$\frac{INDICES_{Current} - INDICES_{Max}}{INDICES_{max} - INDICES_{Min}} \quad \text{----(1)}$$

NDVI products (MOD-13Q1- 006) of MODIS instrument on board Terra satellite at 16 days interval from 1st fortnight of November to 2nd fortnight of February was used, whereas in order to derive the NDWI following equation has been used.

$$NDWI = \left(\frac{NIR - SWIR}{NIR + SWIR} \right) \quad \text{---- (2)}$$

SWIR band reflects both in the vegetation water content and the spongy mesophyll structure in vegetation canopies. The NIR reflectance is affected by leaf internal structure and leaf dry matter content, but not by water content. The combination of the NIR and SWIR band removes variations that induced by leaf internal structure and leaf dry matter content which improves the accuracy in retrieving the vegetation water content.

District wise historical yield data were taken from Department of Economics & Statistics to Government of India which is used as dependent variable in order to estimate the yield along with VCI of NDVI and NDWI.

Stepwise regression approach was used to find out the best fit relation between fortnightly NDVI+NDWI and past years yield data. Stepwise regression essentially does multiple regression a number of times, each time removing the weakest correlated variable and in last only variables remains that explain the distribution best. Regression relation was developed separately for each district, was used to compute the yield of 2017.

3. RESULT & DISCUSSION

Temporal distribution (November 1st fortnight to February 2nd Fortnight) of NDVI of *rabi* rice for the study districts is graphically depicted in fig. 2 and its map is presented in fig. 3. The figure revealed that the highest greenness was noticed over entire Odisha, West Bengal and the part of Karnataka and Telangana in 1st fortnight of November. This greenness is due to late kharif rice or some other kharif crop grown in the same region. After November as the crop grown in *kharif* is harvested, greenness start decreasing and the same conditions prevailed up to 2nd fortnight of December because during this period *rabi* rice was in initial phases.

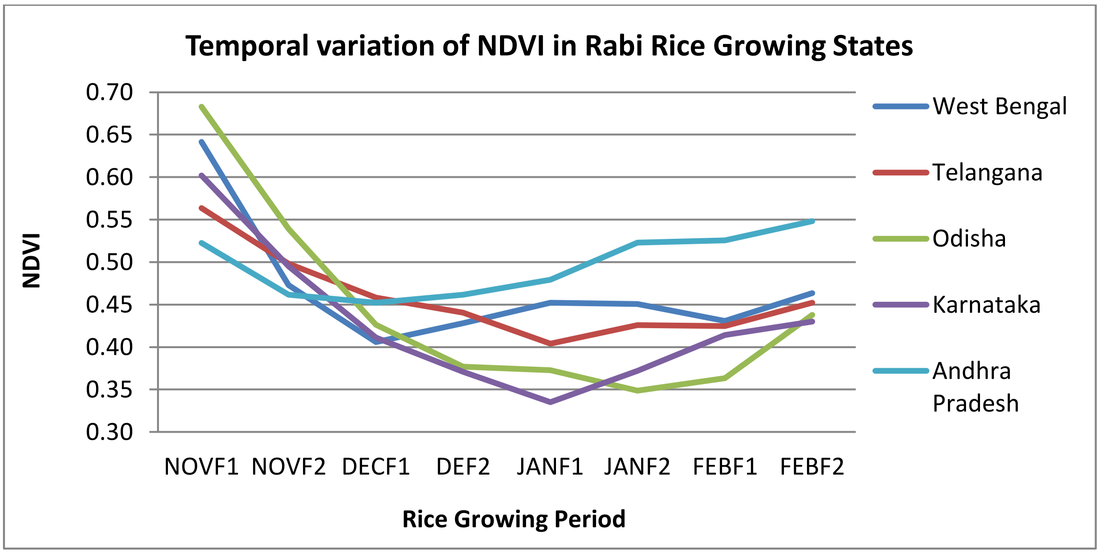

Figure 2: Progress of NDVI during Rabi Rice Growing period of 2016-2017.

Its vigourness starts from Second fortnight of December in Andhra Pradesh & West Bengal whereas in Telangana & Karnataka it NDVI starts increasing from first fortnight of January and in February it was in peak stage over entire growing regions.

VCI was derived using two remote sensing based indices i.e. NDVI and NDWI. The best fit relation between historical yield and VCI of NDVI and NDWI was estimated using stepwise regression (a form of multiple linear regression techniques). It is observed that the VCI of NDVI and NDWI represents up to 90 percent of crop yield. The R square (R^2) given in table 1 revealed that the vegetation Indices correlated very well with historical yield of Odisha. It ranged between 0.7 and 0.9 whereas in few districts of Andhra Pradesh, Telangana Karnataka and West Bengal the correlation is slightly less and it ranges from 0.4-0.9, 0.3-0.8, 0.3.-0.7 and 0.2-0.8 respectively. Similarly Adjusted R^2 which is a modified version of R^2 that has been adjusted for the number of predictors in the model is also varies from 0.4-0.9, 0.3-0.8, 0.3-0.7, 0.7-0.9 and 0.2-0.8 for the districts of Andhra Pradesh, Telangana Karnataka, Odisha and West Bengal, respectively.

Adjusted R^2 indicates how well terms fit a curve or line, but adjusts for the number of terms in a model. If more useless variables added to a model, adjusted R^2 will decrease whereas if more useful variables added, adjusted R^2 will increase. R^2 simply assumes that every single variable explains the variation in the dependent variable whereas adjusted R^2 tells the percentage of variation explained by only the independent variables that actually affect the dependent variable.

Table 1: Relationship between VCI of NDVI & NDWI and historical yield

States	**R^2**	**Adj R^2**	**F Values**
Andhra Pradesh	0.4-0.9	0.3-0.9	7.4-275
Telangana	0.3-0.8	0.2-0.8	4.8-32.5
Karnataka	0.3-0.7	0.1-0.7	1.8-15.9
Odisha	0.7-0.9	0.6-0.9	16.3-56.1
West Bengal	0.2-0.8	0.1-0.8	3.3-34.1

Significant variation in VCI derived yield was noticed over the entire growing region as VCI changes. VCI derived yield presented in Table 2 revealed that the district wise yield varies from 3378-4432, 2551-3940, 2071-5186, 1702-4810 and 2907-4015 kg ha^{-1} for the state Andhra Pradesh, Telangana, Karnataka, Odisha and West Bengal, respectively. DES yield (average of latest available 3 year yield) in these states range from 3433-4751, 2736-3845, 1827-3678, 2333-4008 and 3075-3950 kg ha^{-1}, respectively. Since, the district level official yield values were not available for comparison, only the ranges have been compared to show that the estimated yield values are in the similar range. Within the state highest variation among the districts was noticed for Karnataka & Odisha state whereas variation was very less for Andhra Pradesh.

Table 2: Yield (kg/ha) estimated from Vegetation Condition Index based models

States	**Range of District level Estimated Yield, 2017**	**Mean**	**CV%**	**Range of District level DES yield (3 Yr Average)**
Andhra Pradesh	3378-4432	3964.0	9.3	3433-4751
Telangana	2551-3940	3293.0	15.2	2736-3845

Karnataka	2071-5186	4099.1	35.4	1827-3678
Odisha	1702-4810	3353.4	35.4	2333-4008
West Bengal	2907-4015	3414.7	10.2	3075-3950

Comparative statement of VCI derived yield and DES yield (average of latest available 3 year yield) is depicted in Figure 4 indicates that the VCI derived yields are very close to DES yield (R^2=0.549).

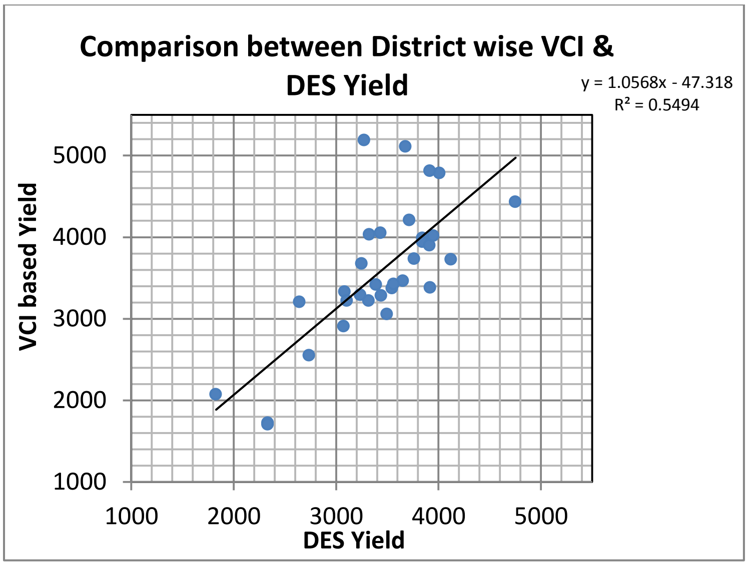

Figure 4: Comparison between district wise VCI yield (2017) *vs*. DES yield (average of latest available 3 year) of Rabi Rice

4. CONCLUSION

From the study it is observed that VCI derived through NDVI and NDWI is an important parameter which has ability to explain the variability up to 90 %. Hence it can be used as an operational predictor for the estimation of rice crop in the country. In some places the relation between VCI and yield is poor for those situation high resolution data and proper ground truthing can improve the accuracy. Study is liable to replicate in some other regions and few more years to determine the usefulness of model and predictor.

5. ACKNOWLEDGMENT

This study was carried out under the FASAL project of the Department of Agriculture, Cooperation and Farmers’ Welfare. The authors are thankful to the Secretary, Department of Agriculture, Cooperation & Farmers’ Welfare Dr. S. K. Pattanayak, and the Joint Secretary (IT) Sh. Dinesh Kumar for their keen interest in the work. Thanks are due to the FASAL team members of MNCFC for providing the rice crop map.

6. REFERENCES

Dadhwal, V.K. and Ray, S.S., 2000. Crop Assessment using remote sensing – Part II: Crop condition and yield assessment. Indian J. Agric. Economics, **55** (2, Suppl.), pp. 55-67.

DES. Department of Economic & Statistics, Government of India (http://aps.dac.gov.in/APY/Public_Report1.aspx)

Dubey, S.K.; Gavli, A.S.; Yadav Sundeep; Sehgal Seema & Ray S.S., 2016. Index based approach of yield forecasting for sugarcane (*Saccharum officinarum*) crop in India. In *Proceedings of 4th International Agronomy Congress (Extended Summaries Vol. 2, 707-708).* Indian Society of Agronomy.

Gao, B. C., 1996. NDWI—A normalized difference water index for remote sensing of vegetation liquid water from space. *Remote sensing of environment*, *58*(3), pp. 257-266.

Kogan, F. N., 1990. Remote sensing of weather impacts on vegetation in non-homogeneous areas. *International Journal of Remote Sensing*, *11*(8), pp. 1405-1419.

Lobell, D. B., 2013. The use of satellite data for crop yield gap analysis. *Field Crops Research*, *143*, pp. 56-64.

Lobell, D. B., & Azzari, G., 2017. Satellite detection of rising maize yield heterogeneity in the US Midwest. *Environmental Research Letters*, *12*(1), pp. 014014.

Parihar, J. S., & Oza, M. P., 2006. FASAL: an integrated approach for crop assessment and production forecasting. In *Proceedings of the Asia-Pacific Remote Sensing Symposium* (pp. 641101-641113). International Society for Optics and Photonics.

Ray, S. S., Neetu, Mamatha, S. and Gupta, S., 2014. Use of Remote Sensing in Crop Forecasting and Assessment of Impact of Natural Disasters: Operational Approaches in India. Proceedings of the FAO Expert Meeting on Crop Monitoring for Improved Food Security, Vientiane, Lao PDR; 17 February 2014. (Ed.: M. K. Srivastava). RAP Publication 2014/28. FAO and ADB, 2015. pp. 111-112.

Son, N. T., Chen, C. F., Chen, C. R., Minh, V. Q., & Trung, N. H., 2014. A comparative analysis of multitemporal MODIS EVI and NDVI data for large-scale rice yield estimation. *Agricultural and forest meteorology*, *197*, pp. 52-64.

Van Wart J, Kersebaum K C, Peng S, Milner M and Cassman K G, 2013. estimating crop yield potential at regional to national scales F. Crop. Res. 143, pp. 34–43.

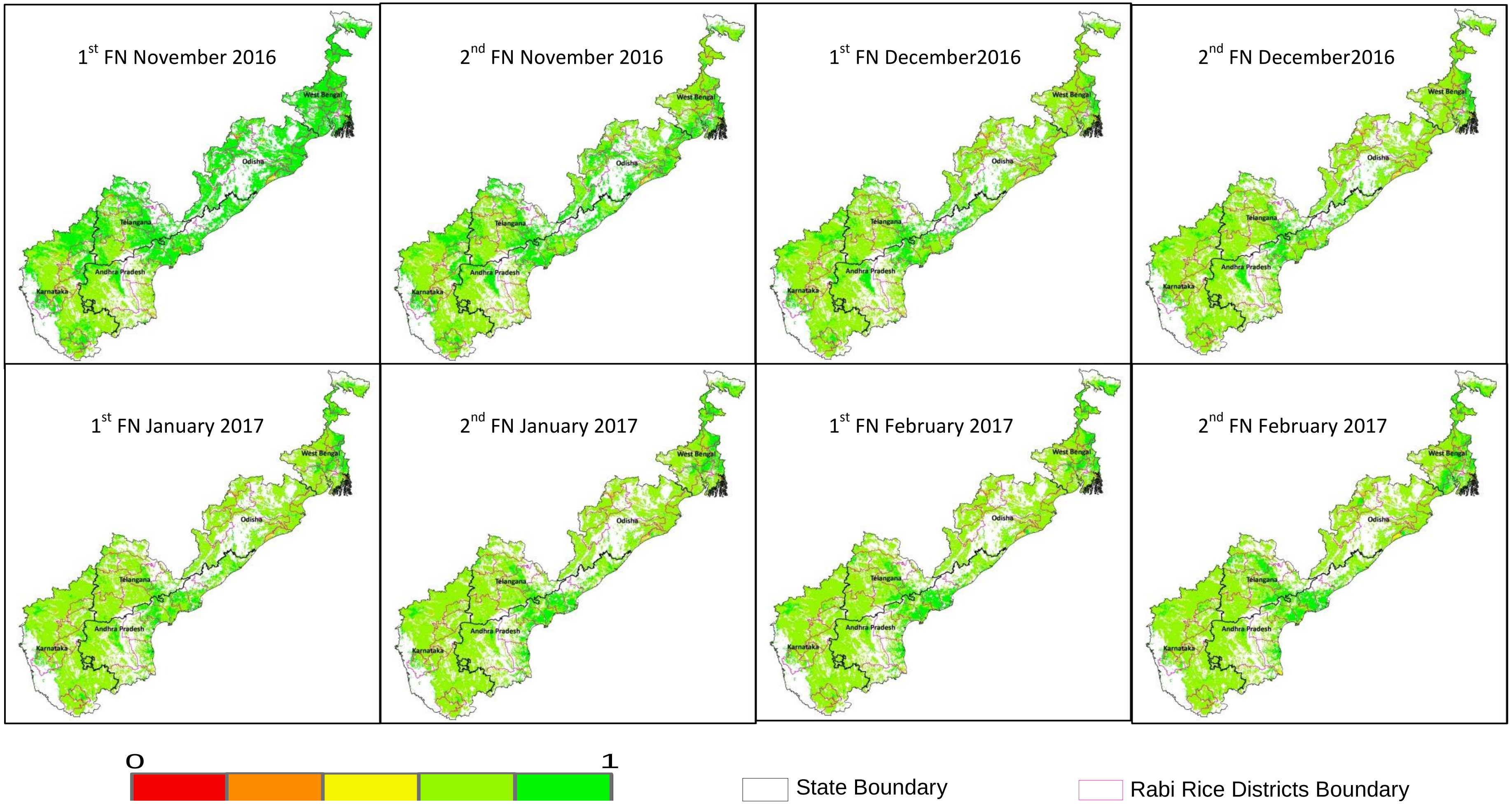

Fig 3: Progress of NDVI in Rabi Rice growing stats during November to February