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Research Article

Efficiency of remote sensing indices in crop biotic stress assessment

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Abstract

In this study, an attempt has been done to discriminate healthy and pest affected area using remote sensing based indices such as NDVI and LSWI. NDVI and LSWI profile of healthy and pest affected crop shows large difference. These differences not only confirmed the capability of remote sensing indices in detecting crop disease, but also demonstrated that the spectral indices based classification method can be effective tool to separate healthy and diseased crop. An attempt is made on identification of probable hot spots for the mealy bug pest concentration zones of cotton crop in large areas as a synoptic perspective for Sirsa district.

Keywords: NDVI, LSWI, mealy bug, Severity Index and remote sensing

Introduction

Mealy bug (*Phenacoccus solenopsis*) is one of the pests seem to be predominant in cotton. Its occurrence is sporadic in nature and is reported that its outbreak occurs after first picking due to its contagious nature dispersed through clothes of the farmers or carried by the weeds bordering along the farm lands. This was the major pest during the Kharif season 2010 in cotton growing region in northern India.

SWIR band is absorbed by water, be it free water bodies or the water contained in plant cells (Gao, 1996). SWIR is very sensitive to canopy water content, green vegetation absorb SWIR and lead to less reflectance which show the healthy condition of vegetation.

Shortwave infrared (SWIR) band is sensitive to vegetation cover, leaf moisture and soil moisture. The spectral response in the short wave infrared band increases when the vegetation senesces due to loss of water in leaf tissue (Tucker, 1980). The decrease in absorbance in SWIR bands leads to higher reflectance's which show water stress or disease in vegetation due to less turgid plant cells in the canopy (Ceccato *et al.*, 2001). Changes in the SWIR spectral region are frequently associated with water stress in vegetation and infestation with balsam woolly adelgid which reduces water flow and results in the tree being in a state of physiological drought (Puritch, 1973).

Absorption of incident light changes in the visible and NIR range is probably due to the decreased chlorophyll content, changes in other pigments, and foliar internal structure. The change of absorption consequently influences the reflectance of stressed plants (Knapp and Carter, 1998).

Materials and Methods

Sirsa district in Haryana is the major cotton belt in North India. It lies in arid hot agro ecological zone of India. In Kharif season, major crops are cotton and rice. The time of cotton

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sowing is from May to June and the picking is done in the month of October - November.

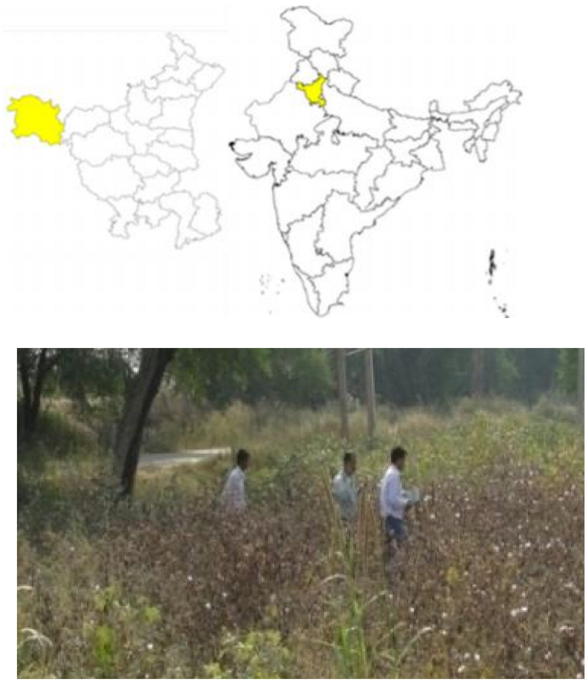

Fig. 1: study area map (left) and field location of infestation (right)

The pest infested locations (Fig. 1) were collected during ground truth survey for cotton growing areas in Sirsa district in 2010. The positions of the pest affected fields were recorded using GPS from August to October. Different grading of pest severity was used such as 0- no mealy bug, 1 - about 1-10 mealy bug scattered over the plant, 2-One branch infested heavily with the mealy bug, 3- two or three branches infested heavily with the mealy bug upto 50% plant affected and 4-complete plant affected. Normalized Difference Vegetation index (NDVI), (ρnir-ρred)/ (ρnir+ρred) and Land surface water indexis (LSWI), (ρnir-ρswir)/ (ρnir+ρswir) remote sensing indices has been analyzed in this study. Where ρnir, ρred and ρswir stands for reflectance in NIR, Red and SWIR band respectively. ISODATA clustering technique was applied over the stacked multi-date NDVI images to classify the different land covers in study area. Cotton crops were separated from other land covers based on the ground truth sites. For the pest effect assessment, Spectral signature of pest affected as well healthy crops has been generated for different sites in study area. Relationship between spectral signature and severity of pest has been analyzed. Ground truth sites having high correlation with spectral profile of remote sensing indices have been used in final model development. Final developed model was applied in cotton mask pixels using ERDAS imagine module.

Result and Discussion

Land use land cover pattern of study area

Mainly four classes were categorized in the study area cotton, rice, water, and non-crop. Rice and cotton was the major crop of study area. Rice is mainly along the Ghaggar river while cotton is distributed in the study area. False Color Composite (FCC) image of the Sirsa district is shown in Fig. 2 (left) and the classified map of Sirsa district are shown Fig. 2 (right).

Relationship between LSWI and Severity Index

From the analysis of the Figure, it was found that LSWI was highly negatively correlated with Severity Index. As leaf water content increases, SWIR bands decreases due to absorption (Ceccato *et al*., 2001). Spectral signal is dominated by non-photosynthetic vegetation and the soil background, resulting in the lowest LSWI values (Boles *et al*., 2004). Fig. 3 explains the relation between pest incidence and LSWI. LSWI decreases as the severity index increases. Decrease in LSWI value shows spectral signature is dominated by non-photosynthetic vegetation. Also indicates that as severity index increase, plant leaf structure damaged and leaf water content decrease.

Relationship between NDVI and Severity Index

From the analysis of Figure, it was found that NDVI is highly negatively correlated with severity index. When plants get stressed, such as by pest /

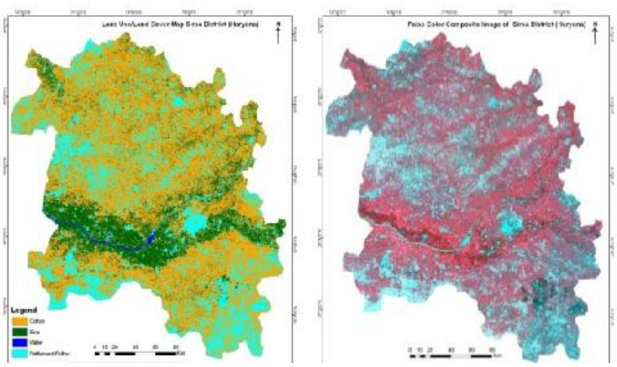

Fig. 2. False color composite (Left) and classified map (right)

disease, their absorption of incident light changes in the visible and NIR range (Carter and Knapp, 2001).

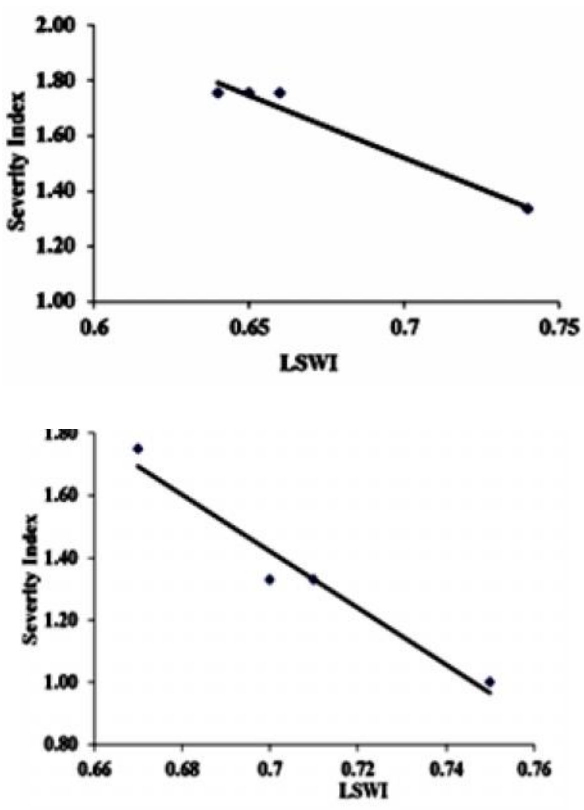

Fig. 3. Relationship between LSWI and Severity Index at different sites

Fig. 4 shows negative correlation between NDVI and severity index. Which is due to plant leaves structure get damages as NIR reflectance known for leaf structure and red for chlorophyll known for leaf structure and red for chlorophyll content in plant leaves. as plant get stressed due to pest, plant leaves structure get damaged and chlorophyll concentration get decrease. As a result, red absorption decrease and reflectance increase which indicate pest or water stress plant stress. As plant's spongy cell tissue structure get damaged, multiple internal reflection decrease in NIR band.

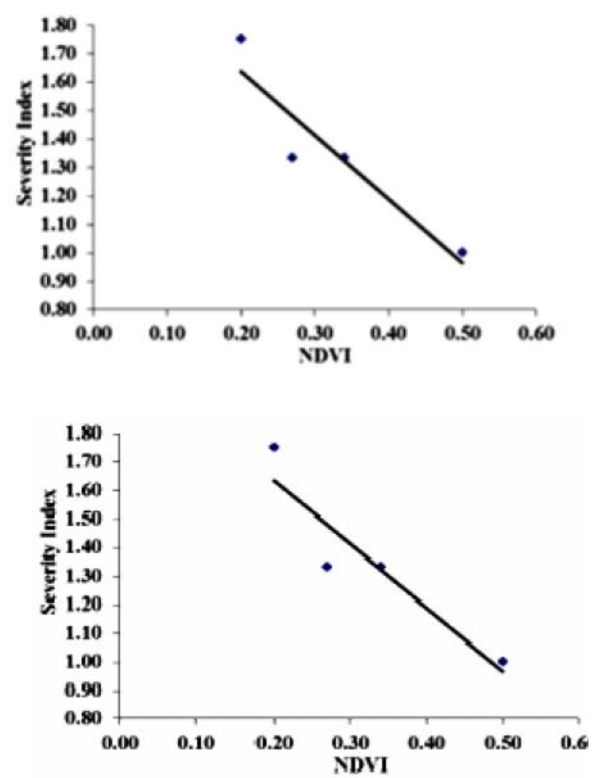

Fig. 4. Relationship between NDVI and Severitv Index at different sites

Fig. 5 explain the separation of spectral profile of NDVI and LSWI between healthy and stress crop. Fig. 5 also shows that as the value of both indices decrease but spectral profile of disease was very low as compared to healthy crop.

Development of LSWI and NDVI based model

$Y = 11.586 - 7.728 \times NDVI^{*} - 11.597 \times LSWI^{**}$ -- (1)

$R = 0.926$ $r^2 = 0.857$ Adj. $r^2 = 0.835$ $n = 17$

* Sig. at 0.010,

** Sig. at 0.043,

Where, Y = Severity Index

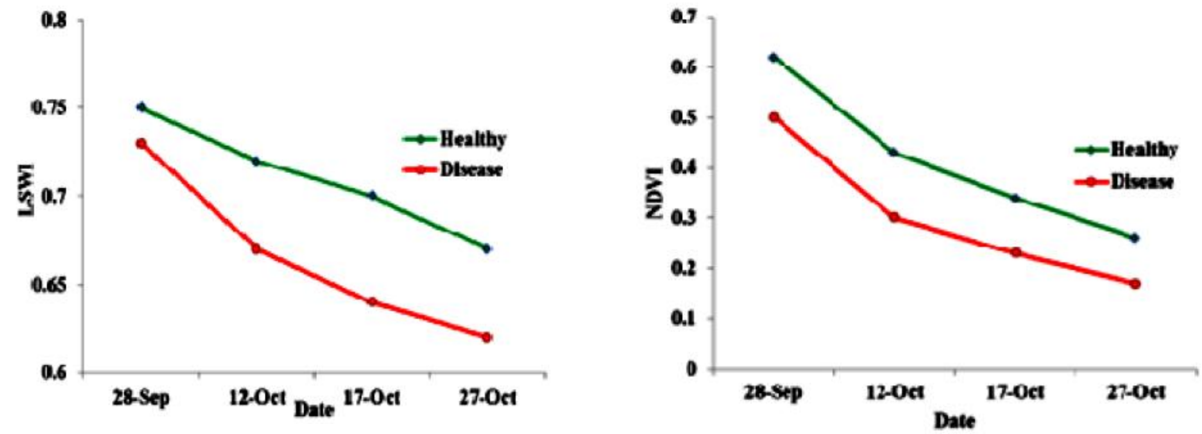

Fig. 5. Comparison of spectral profile Healthy and Disease crop at different sites

In the above mentioned Model, it was also found that both NDVI and LSWI are negatively correlated with severity index and weightage of LSWI is more as compared to NDVI.

Validation of Model

Validation using blind sites (excluding data points taken for model development) is shown in Fig. 6.

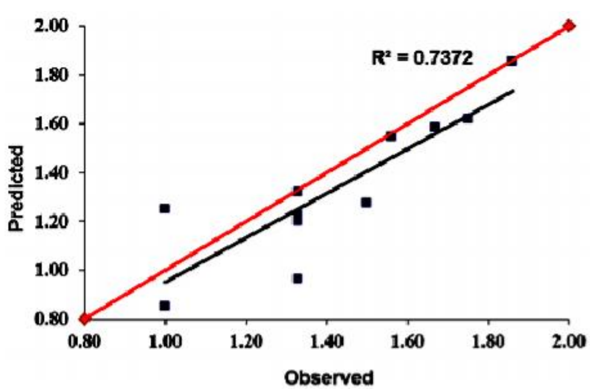

Fig. 6. Validation of blind sites for pest incidence level

Fig. 6 illustrate that most of the point close to 1:1 red line which shows that model capture the pest infestation zone in cotton crop. coefficeint of determination between observed and predicted are quite good which shows that this model can be apply in real time pest infestation zone identification.

Using the Eq.1, based on NDVI and LSWI has been taken as final model, statistical information was more significant and applied on 12 October, 2010 remote sensing data using the Erdas Imagine software's Modeler Module, Spatial distribution of pest effect in cotton is shown in Fig. 7.

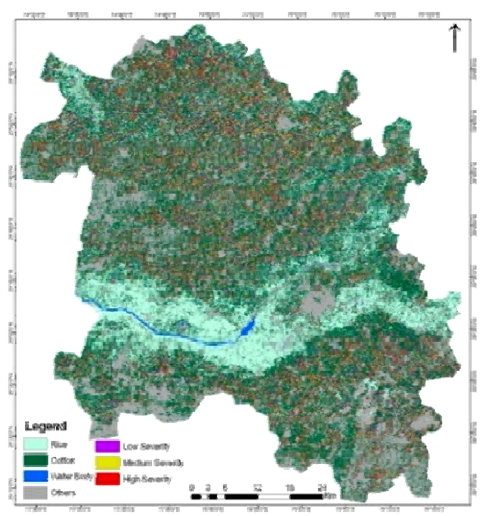

Fig. 7. Spatial Distribution of pest infestation zone in study area

Intensity of severity is classified in three category, low, medium and high severity. Areas with high severity are shown by Red color in map. Purple color shows low severity and yellow color shows medium severity level.

Conclusion

Since both index uses Red, NIR and SWIR wavelength region of spectrum, red region sensitive to chlophyll concentration, NIR, sensitive to plant structure and SWIR sensitive to leaf water content. As pest incidence occur, chlorophyll concentration decrease which indicate stress level in plant. Changes in plant leaf structure lead to decrease in NIR reflectance show leaf structure damage while SWIR is sensitive to leaf water content, increase in SWIR region leading to water stress or pest stress. This methodology capture pest affected crops will help in pest management. High spatial level meteorological parameters as well as soil moisture data may be included in to improve the measurement.

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