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Derivation of grassy weed intensity maps in wheat using spatial data with GIS in the central districts of Punjab

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ABSTRACT

An experiment was conducted to generate weed intensity maps using spatial data with GIS and remote sensing in the central districts of Punjab, India. Remote sensing technologies are playing an increasingly important role in agricultural production. Because of their potential for high spatial and spectral resolution, satellite and aircraft images can contain detailed site specific information about conditions in agricultural fields. It can be used for monitoring crop growth, yield potential, soil conditions, weed intensity *etc*. For the commercial extension of site-specific herbicide application technology, rapid and cost effective methods for creating accurate weed maps are required. The objective of this research was to demonstrate the potential of optical airborne remote sensing in the detection of some specific weeds and their densities in wheat crop in the central districts of Punjab (India). The analysis of spectral and ground measurement was done to select wave bands (wavelength regions) suitable for distinguishing weed-infested and weed-free crop areas.

Key words: Wheat, *Phalaris minor, Avena ludoviciana,* Weed intensity, Remote sensing and GIS

The general reflectance properties of green vegetation have been well established. Reflectance is low in the visible range (approximately 400-750 nm), with a peak in the green region centred at approximately 550 nm, and lower reflectance in the adjacent blue and red regions. Chlorophyll and other pigments are primarily responsible for the response in the visible region. The transition to the NIR region is characterized by a sharp increase in reflectance, referred to as the red edge. Water dominates the response in the NIR region. The band between 800 and 1350 nm is relatively flat and known as the NIR plateau. The plateau region transmits light readily (Gates *et al.* 1965, Myers *et al.* 1966, Noble 2001), which may have implications for the use of NIR 2 measurements taken under field conditions. This plateau is followed by a lower reflectance region due to major water absorption bands at 1450 and 1950 nm, with regions of increased reflectance in between (Noble 2002).

Documenting the reflectance properties of various crop and weed species has been the subject of numerous studies (Allen *et al.* 1970, Billings and Morris 1951, Everitt *et al.* 1986, Everitt and Richardson 1987, Gausman *et al.* 1969, Gausman and Allen 1973, Gausman *et al.* 1981, Gausman and Leamer 1981). These types of studies were concerned primarily with measuring reflectance values with a view to satellite or aerial remote sensing and describing the relationship between leaf structure and leaf reflection. A review of factors affecting leaf reflectance was presented by Grant (1987) while several of these studies included some discussion on discrimination based on spectral features and sufficient sample size for meaningful classification.

Weed detection using image analysis was directed through different approaches. Initial experimental works were based on the spectral signature of weeds and crops. Vrindts and de Baerdemaeker (1997) determined some specific spectral bands to achieve weed identification. Statistical analyses were conducted to find spectral properties of each species. In the same way, Pollet *et al.* (1998) developed an imaging spectrograph. This device gave an image with the spatial dimension on vertical axis and the spectral dimension on horizontal axis. Biller *et al.* (1997) achieved a sensor to detect plants on bare soil. In this case, two optical bands as red (650 nm) and infrared (850 nm) were used to find vegetation. Finally, last approach concerned remote sensing imaging. Aerial images taken with four cameras equipped with optical band-pass filters were used by Rew *et al*. (1999) to discriminate weeds and crops. Weeds were detected by a significant increase in NDVI (normalized difference vegetation index). All these previous approaches were conducted in order to discriminate weeds and crops from their spectral signature or shape.

Technologies of remote sensing and precision agriculture are, in combination, playing an increasingly important role in agricultural production. Because of their potential for high spatial and spectral resolution, satellite and aircraft images can contain detailed site specific information about conditions in agricultural fields. They can be used for monitoring crop growth, yield potential, soil conditions, weed intensity *etc*. (Thomasson *et al.* 2003). Vegetation indices (VI's) and derived metrics have been extensively used for monitoring and detecting vegetation and land cover change (de Fries *et al*. 1995). Spectral reflectance from image data has often been used to calculate vegetation indices that have been related to crop growth status. The development of vegetation indices is based on differential absorption, transmittance and reflectance of energy by the vegetation in the red and infra red regions of the electromagnetic spectrum (Jensen 1996). Normalized difference vegetation index (NDVI) is one of the vegetation indices that have been commonly used in remote sensing applications in agriculture. Goel *et al.* (2003) used hyperspectral image classification to detect weed infestations and nitrogen status in corn. They found it difficult to distinguish between the effects of weeds and nitrogen treatments. However, when one factor was considered at a time, maps indicating weed infestation or nitrogen treatment could be generated with a satisfactory level of accuracy. Bajwa and Tian (2001) used an airborne digital colour-infrared sensor to acquire remotely sensed images for mapping weed density. Weed densities and species vary field to field and thus uniform application of weed control measures over an entire field is neither economical nor environment friendly. However, such variations within fields have largely been ignored due to technological limitations in the application of herbicides (Medd and Pratley 1998). In precision or site specific crop and weed management, within-field weed variations are considered and patch spraying is used instead of the blanket application of herbicides. This reduces both treatment cost and herbicide loading in the environment (Christensen *et al.* 1998).

Precise weed detection is a prerequisite for both the formulation of a better weed management strategy and its timely implementation. However, for the commercial extension of site-specific herbicide application techno-logy, rapid and cost effective methods for creating accurate weed maps are required (Lamb *et al*. 1999). Presently two different approaches for weed monitoring and patch spraying are being followed. The first approach involves the development of weed maps and decision making prior to the application of herbicides. The other approach is based on the real-time detection of weeds and on decision making at the time of spraying (Rew and Cousens 1998). Fluorescence spectroscopy could be investigated as an efficient tool for weed-crop discrimination (Panneton *et al* 2006). Mapping techniques from the remote sensing domain are superior to conventional ground based methods of vegetation mapping (De Fries and Townshed 1994, Townshed *et al.* 1991)

The objective of this research was to demonstrate the potential of optical airborne remote sensing in the detection of some specific weeds and their densities in wheat crop in the central districts of Punjab (India). The analysis of spectral and ground measurement was done to select wave bands (wavelength regions) suitable for distinguishing weed-infested and weed-free crop areas.

MATERIALS AND METHODS

GIS analysis and preparation of weed intensity maps in ARC/INFO (Version 9.1)

Weed maps were prepared in the GIS environment using ARC GIS 9.1. Following steps were followed to prepare the weed prescription maps (Fig. 1):

1) The districts of Ludhiana, Jalandhar, Kapurthala, Tarn Taran, Shaheed Bhagat Singh Nagar (Nawan Shehar) were selected as study area for preparation of weed maps.
2) The data were collected from farmers' fields in the study area for the weed density (*P. minor* and *Avena* sp. plants/m^2 in wheat plots), X, Y coordinates (latitude-longitude) were noted using global positioning system (GPS).
3) The latitude - longitude data was converted to degree-decimal format. The coverage file (point) was then generated from the location data in Arc GIS.
4) The weed density data was transformed as attribute table and attached to the point file coverage already generated.
5) Then the point file coverage was converted to raster format through Kriging method giving equal distance points.
6) Reclassification was done by applying district boundary as a mask on the generated map.

Generation of wheat mask

a) Three-dates (November, December and January) digital data acquired through Canadian Satellite SAR was classified using logistic modelling.
b) First of all, the non-agricultural and agricultural land areas were segregated.
c) Within the agricultural area, wheat and non-wheat areas were differentiated.
d) Wheat area was detected and weed density map was overlaid on wheat map and the *Phalaris minor* density in the wheat field was mapped.

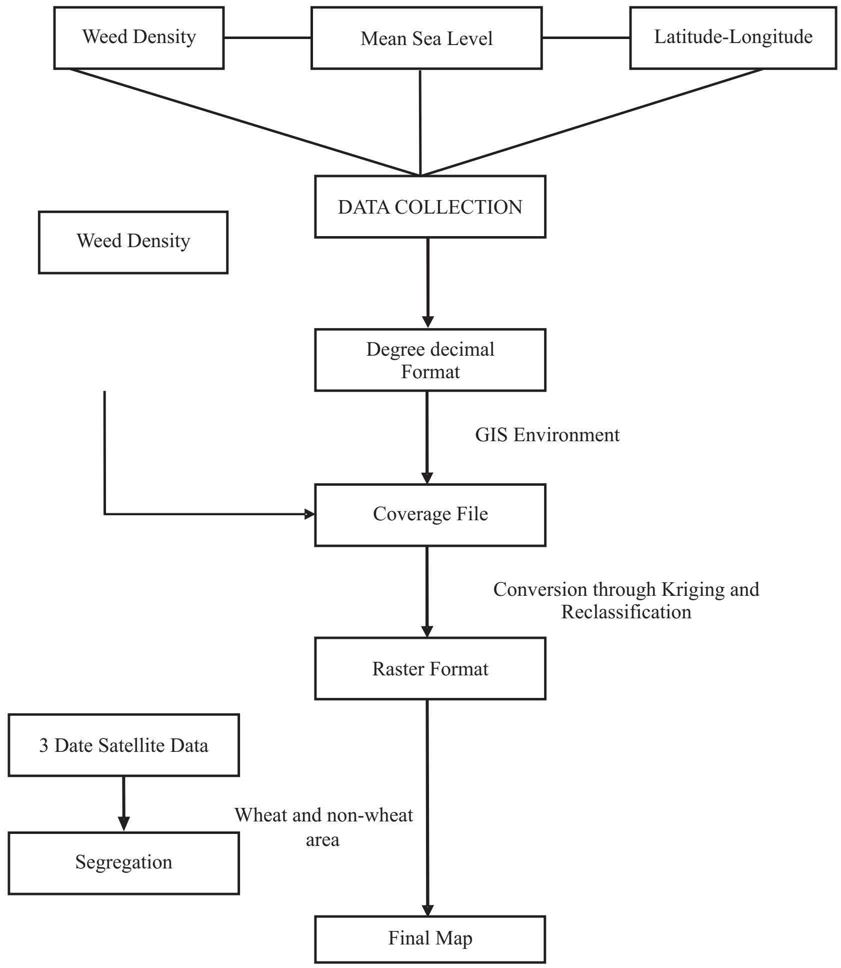

Fig: 1 Weed prescription mapping in the GIS

RESULTS AND DISCUSSION

The per cent area calculated from the maps showed that out of total geographical area (TGA) of Tarn Taran district, 76.28% area was under wheat (agricultural), while remaining 23.91% was non-wheat (non-agricultural). In Kapurthala district 66.24% of TGA was agricultural and 33.75% was non-agricultural. In Jalandhar 60.52% of total geographical area was agricultural and 39.48 per cent was non-agricultural. Similarly in Shaheed Bhagat Singh Nagar and Ludhiana 50.76 and 70.91% of TGA was agricultural and 49.24 and 29.13% was non-agricultural area respectively (Table 1).

Table 1. Distribution of geographical area between the agricultural area and the non agricultural area

District	Total geographical area (TGA) (ha)	Wheat area (ha)	Wheat area (%)	Non-wheat area* (ha)	Non wheat area (%)
Tarn Taran	241.9	184.53	76.28	57.85	23.91
Kapurthala	163.2	108.11	66.24	55.09	33.75
Jalandhar	263.2	159.29	60.52	103.91	39.48
Shaheed Bhagat Singh Nagar	126.0	63.96	50.76	62.04	49.24
Ludhiana	370.2	263.36	70.91	107.84	29.13

* Non-wheat includes built up, rivers, canals, fallow, forests and other crops etc., TGA - Total geographical area

A larger area (38.3%) in Tarn Taran district was infested with *Phalaris minor* density of 15-20 plants/m^2. Eighteen per cent area was infested with a plant density of 20-25 and 15.2%. So a total 76.01% of TGA was infested with *Phalaris minor* with different densities (Table 2).

In Kapurthala, 30.3% area was found to be infested with plant density of 25-30/m^2. In Jalandhar, the area was comparatively lower under specific class but *Phalaris minor* was found in every class from 10 plants upto 50 plants/m^2.

In Shaheed Bhagat Singh Nagar, 44.86 % area was infested with *P. minor* density of 10-20 plants/m^2 and in Ludhiana a larger area i.e. 35.76 % was infested with 15-20 plants of *Phalaris minor*/m^2 followed by 16.77% area under 20-25 plants/m^2. Out of the total geographical area of 370.2 thousand hectare, 262.09 thousand hectare area was recorded to be infested with different *Phalaris minor* densities in Ludhiana district which caused a significant reduction in the yield of wheat in respective districts.

The density of *Avena ludoviciana* recorded under natural conditions in the five districts in central zone of Punjab presented in table 3 showed that *Avena ludoviciana* has spread in all districts under the study area. Highest density of *Avena* sp. i.e. from 5-7 plants/m^2 was recorded in Shaheed Bhagat Singh Nagar and Ludhiana districts. This weed is very competitive and caused significant reduction in yield of wheat crop. Presence of 15 plants/m^2 of *Avena ludoviciana* caused 11.2% reduction in yield of wheat crop. In Tarn Taran, 76.07% area was infested, 66.13 per cent in Kapurthala, 13.27% in Jalandhar, 50.74% in Shaheed Bhagat Singh Nagar and 70.8 % area in Ludhiana was recorded having infestation with density of 1 to 8 plants/m^2 of *Avena ludoviciana* (Table 3).

Among the five districts under study, maximum area (76% of the TGA) was found infested with *Phalaris minor* in Tarn Taran district, which was followed by Ludhiana where 70 % of TGA was infested with *Phalaris minor* with densities ranging from 10 to 40 plants/m^2. In Tarn Taran 15.2% area was infested with higher density i.e. 25 to 35 plants m^2 and in Ludhiana 35.76 % area was infested with 15-20 plants of *Phalaris minor*/m^2.

Regarding infestation of *Avena ludoviciana*, among the study area, maximum area i.e. 76.07% of TGA was found to be infested in Tarn Taran with plant densities ranging from 1 to 5 plants/m^2 and 70.80% area of TGA was infested in Ludhiana district with plant densities ranging from 1 to 8 plants/m^2.

Maximum density of 5-8 plants/m^2 of *Avena ludoviciana* was recorded under Shaheed Bhagat Singh Nagar and Ludhiana districts.

Information on temporal and spatial variation in weed seedling populations within agricultural fields is very important for weed population assessment and management. Primarily, spatial information allows a potential reduction in herbicide use, when post emergent herbicides are only applied to field sections with high weed infestation levels. In a two year study, herbicide use with map-based approach was reduced in winter cereals by 6.81% for herbicides against broad leaved weeds and 20.79% for grass weed herbicides. The efficacy of weed

Table 2. Extent of infestation by *Phalaris minor* in wheat in different districts of Punjab

Density (plants/m^2)	Area (in ha)				
	Tarn Taran	Kapurthala	Jallandhar	Shaheed Bhagat Singh nagar	Ludhiana
<10	0.09	0.16	0.04	4.41	2.93
10-15	6.81	6.15	1.09	44.54	46.51
15-20	92.64	13.16	6.32	11.98	132.4
20-25	43.71	14.7	12.22	1.62	62.04
25-30	15.56	49.27	9.61	0.95	14.65
30-35	21.19	16.03	2.93	0.41	3.43
35-40	4.01	4.39	1.52	0.02	0.13
40-45	-	2.28	0.97	0	0
45-50	-	1.49	0.22	0	0
>50	-	0.29	0.01	0	0
Total area (ha)	241.9	163.2	263.2	126.0	370.2

Table 3. Extent of infestation by *Avena ludoviciana* in wheat in different districts of Punjab

Density (plants/m^2)	Area (in ha)				
	Tarn Taran	Kapurthala	Jallandhar	Shaheed Bhagat Singh nagar	Ludhiana
<1	71.74	61.8	19.74	0	19.98
1-2	2.69	32.96	12.22	24.24	165.1
2-3	64.58	13.17	2.96	0	13.18
3-4	15.04	0	0	0	4.58
4 5	29.97	0	0	0	16.94
5-6	0	0	0.01	13.89	28.98
6-7	0	0	0	25.75	13.15
7-8	0	0	0	0.05	0.18
8-9	0	0	0	0	0
>9	0	0	0	0	0
Total area (ha)	241.9	163.2	263.2	126.0	370.2

control varied from 85 to 98%, indicating that site specific weed management will not result in higher infestation levels in the crops under study (Gerhards and Oebel 2006).

Site specific applications of herbicides offers a lot of potential for reducing the use of synthetic pesticides in agriculture. For corn, it has been estimated that pesticide savings in the order of 50% could be feasible. One of the main limitations for the adoption of precision herbicide application is the availability of quick and economical means of identifying weed patches.

Among the five districts (Jalandhar, Kapurthala, Ludhiana, Shaheed Bhagat Singh Nagar and Tarn Taran) under study, maximum infestation by *Phalaris minor* and *Avena ludoviciana* was recorded in Tarn Taran followed by Ludhiana district with respect to area as well as plant density.

Weed prescription mapping study can be used for forecasting the infestations, on the basis of which farmers can be advised to take the preventive control measures which can help in preventing yield losses due to weeds. These weed maps can be used as an input in yield forecasting models.

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