Soil erosion in Punjab

Sharmistha Pal[1,*], G. S. Sidhu[2], A. K. Tiwari[1], Dipak Sarkar[3] and V. N. Sharda[4]

[1]ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Chandigarh 160 019, India
[2]National Bureau of Soil Survey and Land Use Planning, Regional Centre, IARI Campus, New Delhi 110 012, India
[3]National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur 440 033, India
[4]Krishi Anusandhan Bhavan-I, Pusa, New Delhi 110 012, India

Soil erosion map of Punjab highlights the degree of soil erosion caused by water in the state. The values of soil loss per annum from each grid location were quantified using universal soil loss equation (USLE) and used in GIS for preparing the soil erosion map of Punjab state. About 87% of the total geographical area of Punjab has annual soil loss below 5 Mg ha^{-1} and does not require specific soil conservation measures. About 4.02% of the area is affected by annual soil loss of >15 Mg ha^{-1}, which includes moderately severe (0.88%), severe (1.72%) and very severe (1.42%) soil loss @ 15 to 20, 20 to 40 and 40 to 80 Mg ha^{-1} respectively. This necessitates the development of improved technologies (conservation agricultural practices, contour bunding, contour cultivation, etc.), which need to be adopted for improving the productivity on a sustainable basis.

Keywords: Conservation planning, Punjab, soil loss, universal soil loss equation.

ASSESSMENT of severity of soil erosion and its prioritization for designing soil and water conservation measures is a challenging task due to lack of reliable data base. Globally, out of the total land area of 13.5 billion ha, about 2 billion ha (15%) is affected by water erosion[1]. This may lead to a loss of 1.4–2.8% of the total agricultural, pasture and forest land by 2020 (ref. 2). The different kinds of land degradation in India has affected around 120.72 million ha area, the highest (68.4%) being contributed by water erosion (82.57 m ha)[3].

The decline in production by washing out surface soil through water erosion negatively affects food security[4]. The water erosion removes 13.4 million tonnes soil per year, which amounts to economic loss of US$ 2.51 billion[5].

Singh *et al.*[6] reported water erosion rate of less than 5 Mg ha^{-1} year^{-1} to over 80 Mg ha^{-1} year^{-1} in Shivalik. Velayutham and Bhattacharya[7] reported 5–50% loss of productivity due to moderate erosion of 10–20 Mg ha^{-1} year^{-1}. The state level soil loss maps have been prepared using universal soil loss equation (USLE) for Gujarat[8], Maharashtra[9] and Kerala[10]. Yadav and Sachdev[11] reported that 77.07%, 17.28%, 2.87%, 1.09%, 1.09% and 0.43% of the area in Haryana experienced soil loss in the range of <5, 5–10, 10–15, 15–20, 20–40 and >40 Mg ha^{-1} year^{-1} respectively. In Himachal Pradesh, Yadav and Sidhu[12] reported erosion rates from 0.08 to 683.10 Mg ha^{-1} year^{-1}.

In the Shivalik of Punjab, each centimetre loss of surface soil has been reported to decrease maize yield by 103 kg ha^{-1} (ref. 13). Keeping in view the urgency of mapping soil erosion in Punjab based on real time data base as generated through the Soil Map of India Project for other states, the present study has been attempted.

Punjab lies between 29°30′N and 32°32′N lat. and 73°55′E and 76°55′E long., with an area of 5.03 m ha and covers 1.5% of the total geographical area of India. The soils of Punjab are grouped into four orders, viz. Inceptisols, Entisols, Aridisols and Alfisols. The mean annual rainfall ranges from 300 mm (Abohar) to 1200 mm (Pathankot), with an average of 705 mm. The soil erosion in Punjab is mostly caused by rain water.

The USLE[14] is an empirical model that estimates mean soil loss from a field. This equation predicts losses from sheet and rill erosion only. The rills are small intermittent water courses, usually only a few inches deep. The gully is a deep ditch cut by running water. Soil loss (A) in Mg per hectare per year is computed by the following equation

$$A = R \times K \times L \times S \times C \times P. \quad (1)$$

The factor R is the annual total value of the erosion index (EI_{30}) for a specific site. Rainfall erosivity (R) is expressed in Mega Joules-millimetre (MJ-mm) per hectare-hour-year (ha h year). It is computed as the product of rainstorm kinetic energy (KE) and the maximum intensity for 30 min duration and added for all storms in a year. The KE of storm in metric unit is calculated by the equation developed by Wischmeier and Mannering[15].

Ram Babu *et al.*[16] collected the rainfall data of 50 years from automatic rainfall recorder for 45 stations in India and computed EI_{30} value for each storm. Linear relationships were established between mean annual erosion index (Y_A) and mean annual rainfall (X_A) and seasonal erosion index (Y_S) and average seasonal rainfall (X_S) (eqs (2) and (3)).

$$Y_A = 79 + 0.363X_A \quad (r = 0.83), \quad (2)$$

$$Y_S = 50 + 0.389X_S \quad (r = 0.88). \quad (3)$$

From these values and additional data from 225 stations, iso-erodent map of India showing R-values of different parts of country including Punjab was prepared. These stations are located in districts, tehsils and some selected blocks of the state. These values were used as a source for confirming R-value of different grids. In addition, 30 years' data of monthly rainfall for 20 stations of the state

*For correspondence. (e-mail: sharmistha.ars@gmail.com)

were collected and annual and seasonal R-values were computed using the regression equations of Ram Babu *et al.*[16]. Spatial estimation of rainfall erosivity is computed from the climate data of a given station and then converting point data into polygon data through krigging techniques of GIS.

The K factor is a measure of erodibility of a particular soil under the standard condition of unit USLE plot, under continuous fallow. It is measured in Mg ha h/ha MJ-mm. It was calculated from soil erodibility monograph[14], by putting the values of texture, organic matter, structure and permeability of soil. It can also be calculated using eq. (4). The values were taken from the 586 grids soil data collected by NBSS&LUP during soil resource mapping of the state and analysed in the laboratory.

$$100\,K = 2.1\times10^{-4}\ \mathrm{M}^{1.14}(12-a)+3.25(b-2)+2.5(c-3), \quad (4)$$

where M is particle size parameter (per cent silt + per cent very fine sand) (100% clay); a the percentage of organic matter; b the soil structure code (very fine granular 1, fine granular 2, medium or coarse granular 3, blocky, platy or massive 4) and c is profile permeability class (rapid 1, moderate to rapid 2, moderate 3, slow to moderate 4, slow 5, very slow 6).

The L factor is the ratio of soil loss from the field slope length to that from standard plot (22.13 m) length under similar conditions and slope steepness (S) factor is the ratio of soil loss from the area with specified cover and management to that from a 9% slope under similar conditions. Combined values of LS factor for different lengths and degrees of slope have been compiled[17] and these were used to obtain LS value for different grids.

The C factor is the ratio of soil loss from an area with particular cover and management condition to a similar area in continuous fallow. The preliminary data for estimating cover and management factor for various crops grown at a particular grid has been taken from the profile data sheet[18] district-wise statistics of Punjab[19] and compilation of Singh *et al.*[20].

The P factor is the ratio of soil loss with a particular support practice to the corresponding loss with up and down cultivation. The C factor was identified on basis of the cropping intensity in different districts. Maximum C factor of value '1' is taken from clean cultivated field, i.e. without any crop cover and the value decrease with increase of cropping intensity. The values of these factors have been worked out by different researchers and compiled by Singh *et al.*[20] and Wischmeier and Smith[14]. The main conservation practices followed at the grid point, were taken from the survey data of NBSS&LUP, Nagpur during resource mapping of Punjab[19] and compilation of Singh *et al.*[20].

The grid information (10 × 10 km) at different geo-referenced locations in Punjab was collected from the soil resource data of Punjab for computation of K, LS, C and P factors. Maps were generated by using GIS through putting point data in a polygon of representative stations by krigging interpolation and creating polygons. The latitude, longitude and soil values for different grid points were used in GIS for generating soil erosion map of Punjab.

Six erosion classes were generated depending on the values of soil loss in the state. The R, K, LS, C and P factors were classified into different classes and presented in the map. Table 1 reveals that the largest area (87.51%) in the state has very slight to nil erosion. Some parts of Dhar and Patahnkot areas constituting about 7.16% of total geographical area (TGA) of the state are affected by moderate erosion as a result of runoff of water on sloppy lands having slopes ranging from 8% to >15% (Figure 1).

Foothills of Shiwaliks, constituting 1.72% of the area is affected by severe erosion due to seasonal streams locally called as 'Choes' during rains and it causes havoc in low lying areas (piedmonts) in districts of Jalandhar, Hoshiarpur, Rupnagar, Nawanshahar, Pathankot and Hoshiarpur. The side slopes in Shiwaliks hills (1.42%) are subjected to very severe erosion due to rapid runoff losses. In Punjab, only 3.14% of the area suffers from severe to very severe soil erosion, which is mainly in Shiwaliks and its foothills in northern parts of the state. This area is also popularly known as the Kandi area.

The maps related to different factors of USLE are shown in Figures 2–6. The erosivity factor (MJ mm/ha h year) data indicates maximum R value (>400 MJ mm/ha h year) was observed in northern parts which are dominantly sub-mountainous areas of Shiwaliks, followed by 300–400 MJ mm/ha h year in the foothills of Shiwaliks, 300–400 MJ mm/ha h year in central parts (alluvial plains) and <200 MJ mm/ha h year in southern parts (sandy areas) of the state. Four classes of C-values were identified in the state, having the maximum area between 0.25 and 0.50 categories. It indicates the maximum crop coverage in the state throughout the year due to intensive crop cultivation, which reduces the soil loss to a large extent. Majority of the state area (41%) has P-value 0.2 to 0.3 and 0.4 to 0.5 and no specific soil conservation measures are required. The remaining areas of the state have P-values in the range of <0.20, 0.4 to 0.5 and >0.5 respectively.

Improved land and crop production technologies such as contour bunding, contour cultivation and conservation agricultural practices may be adopted to enhance the farm productivity on a sustainable basis.

Quantitative assessment of soil erosion in Punjab through USLE showed 87.51%, 6.31%, 2.16%, 0.88%, 1.72% and 1.42% of the area was experiencing soil loss in the range of <5, 5–10, 10–15, 15–20, 20–40 and >40 Mg ha^{-1} year^{-1} respectively. To ensure long-term sustainability of production systems and environmental security, location-specific agronomic, mechanical and conservation agricultural practices need to be promoted

Table 1. Soil loss (A-factor, Mg $ha^{-1}year^{-1}$), Punjab (area in sq. km)

District	Very slight <5		Slight 5–10		Moderate 10–15		Mod. severe 15–20		Severe 20–40		Very severe >40	
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)
Amritsar	4,940.17	96.49	197.67	3.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bathinda	3,214.14	94.81	187.90	5.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Faridkot	1,377.67	93.09	107.60	7.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fatehgarh Sahib	1,125.45	95.38	58.69	4.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Firozpur	4,856.99	91.13	488.81	9.17	3.32	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Gurdaspur	2,463.28	69.39	576.29	16.23	393.36	11.08	97.68	2.75	16.17	0.46	0.00	0.00
Hoshiarpur	1,534.01	46.91	468.55	14.33	289.74	8.86	162.12	4.96	384.30	11.75	367.11	11.23
Jalandhar	2,507.68	94.99	85.41	3.24	54.90	2.08	0.00	0.00	0.00	0.00	0.00	0.00
Kapurthala	1,556.04	94.88	89.73	5.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ludhiana	3,570.78	94.47	127.47	3.37	92.86	2.46	0.00	0.00	0.00	0.00	0.00	0.00
Mansa	2,186.50	100.30	0.81	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moga	2,231.77	100.08	5.69	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mukatsar	2,447.35	93.41	181.96	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nawanshahr	568.00	47.73	115.79	9.73	82.86	6.96	81.29	6.83	218.48	18.36	95.71	8.04
Patiala	3,559.44	97.52	60.04	1.65	16.98	0.47	9.86	0.27	13.02	0.36	1.14	0.03
Rupnagar	943.86	46.73	303.71	15.04	153.84	7.62	92.89	4.60	234.31	11.60	251.19	12.44
Sangrur	4,988.59	98.01	120.99	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	44,071.73		3,177.11		1,087.87		443.85		866.29		715.16	

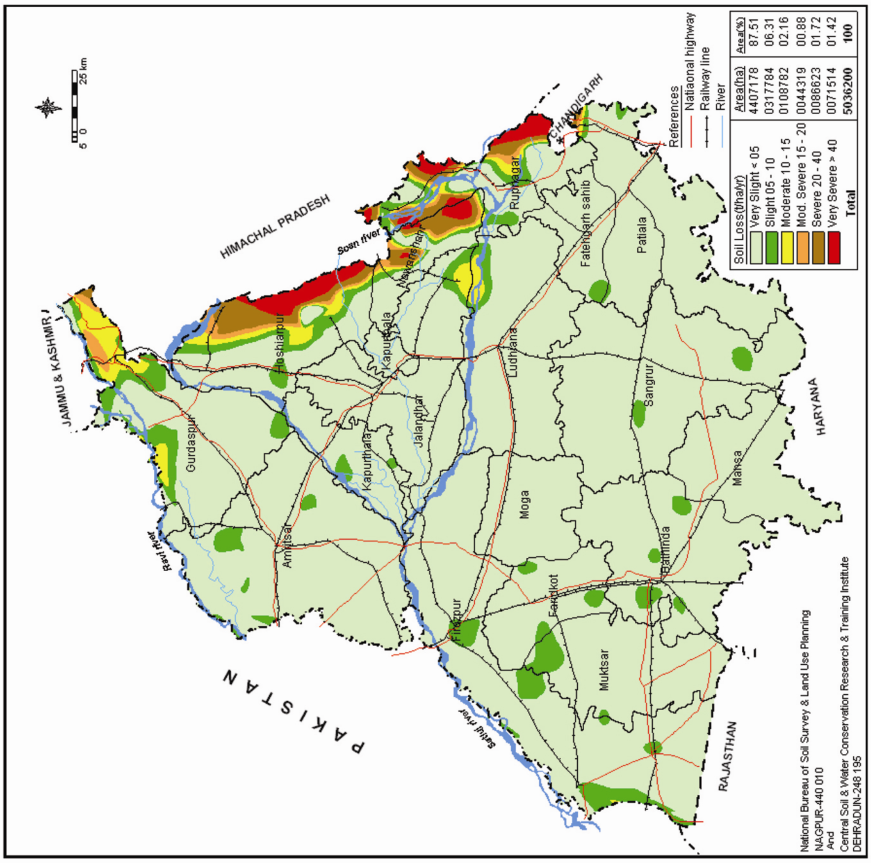

Figure 1. Soil loss (Mg ha^{-1} year^{-1}) map of Punjab.

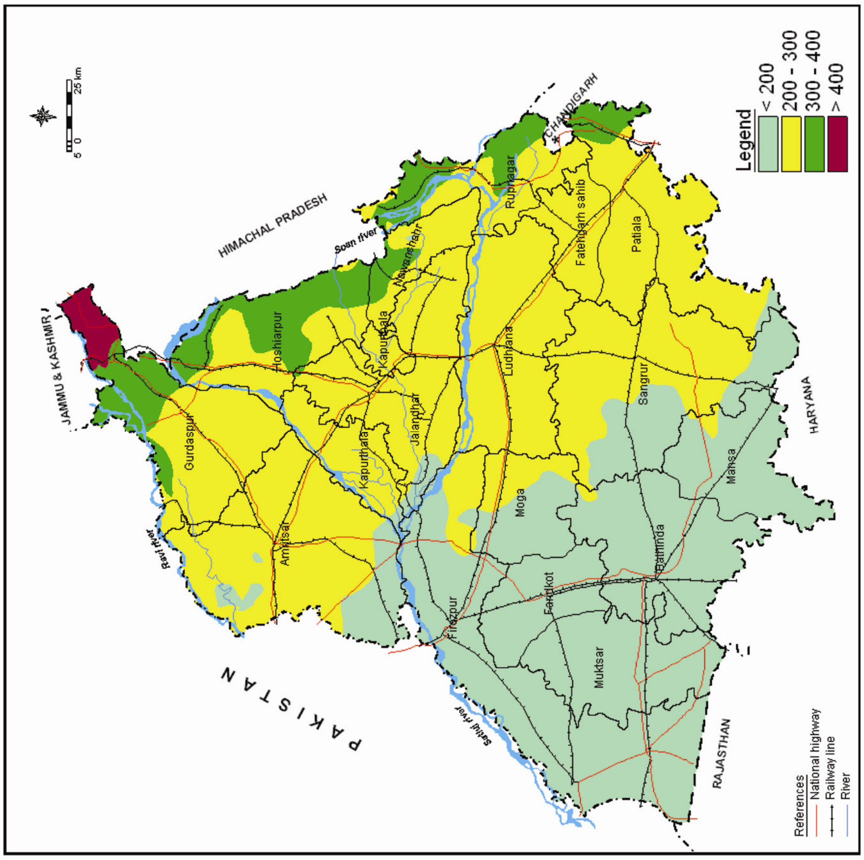

Figure 2. Rainfall erosivity (MJ-mm/ha h year) map of Punjab.

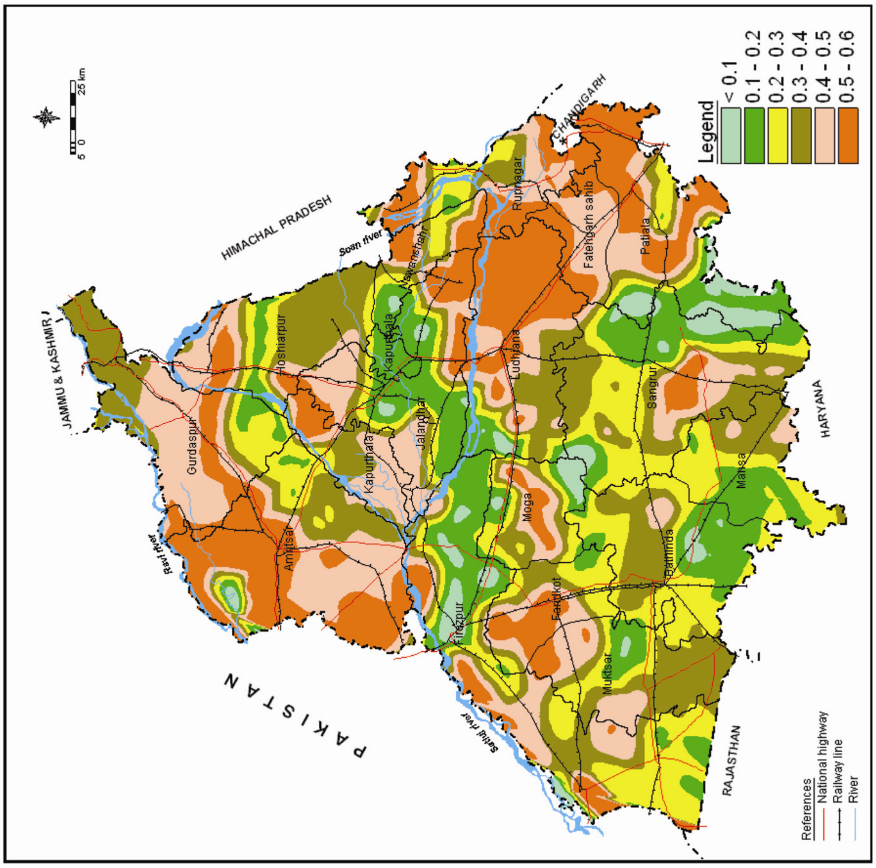

Figure 3. Soil erodibility (Mg ha h/ha MJ mm) map of Punjab.

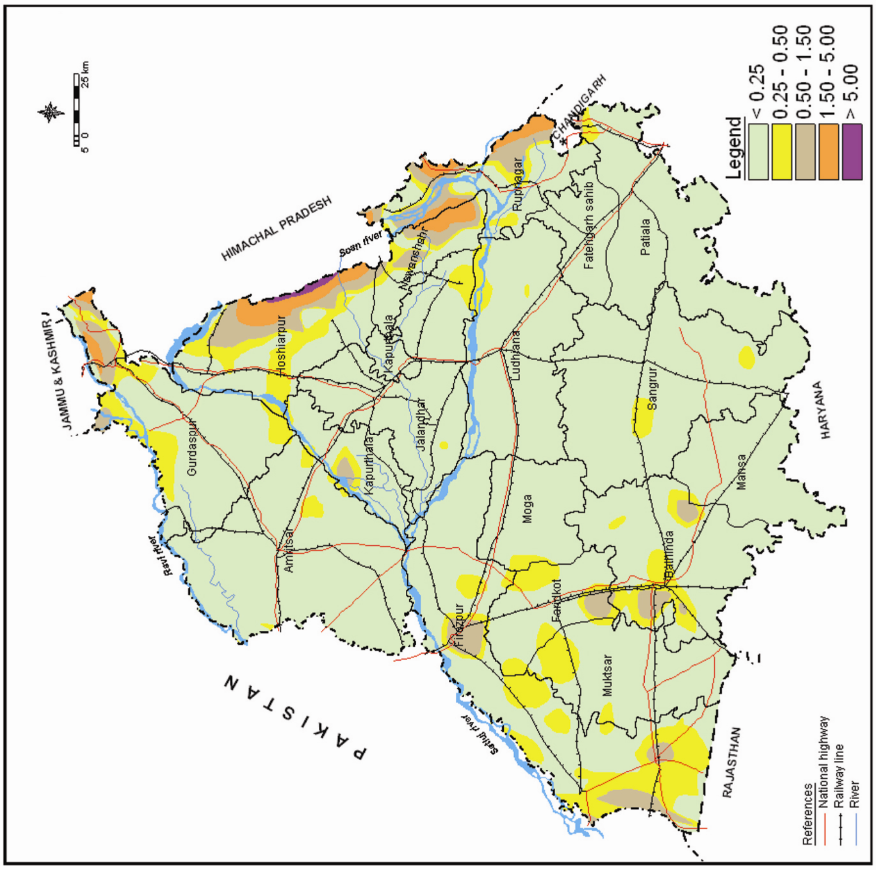

Figure 4. Topographic factor map of Punjab.

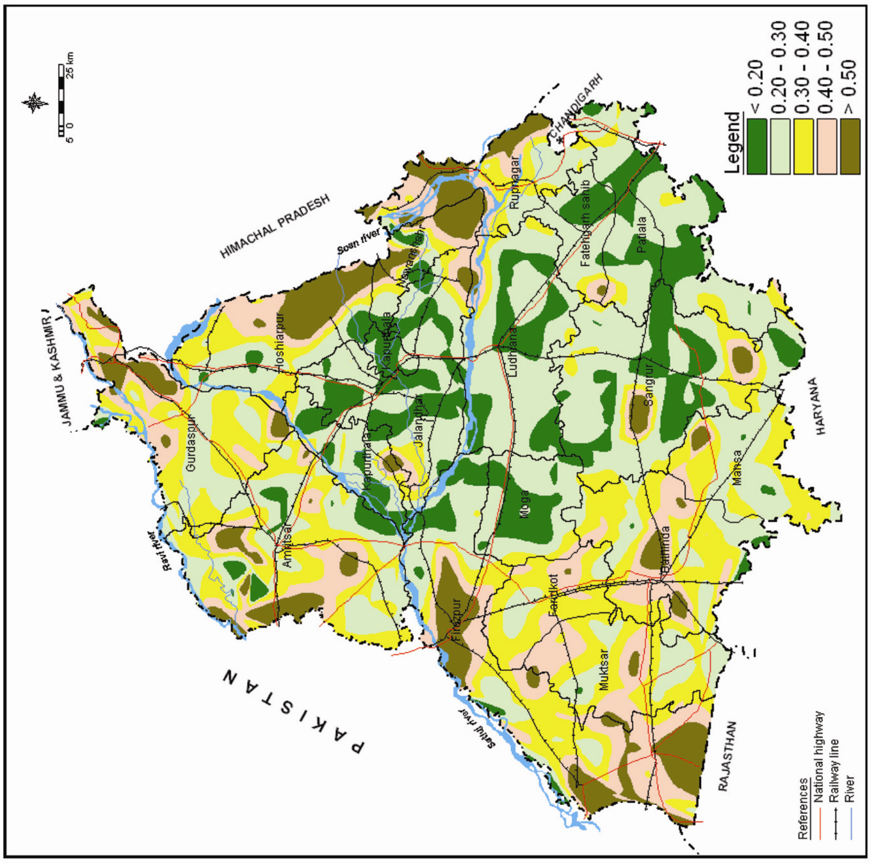

Figure 6. Support practice factor map of Punjab.

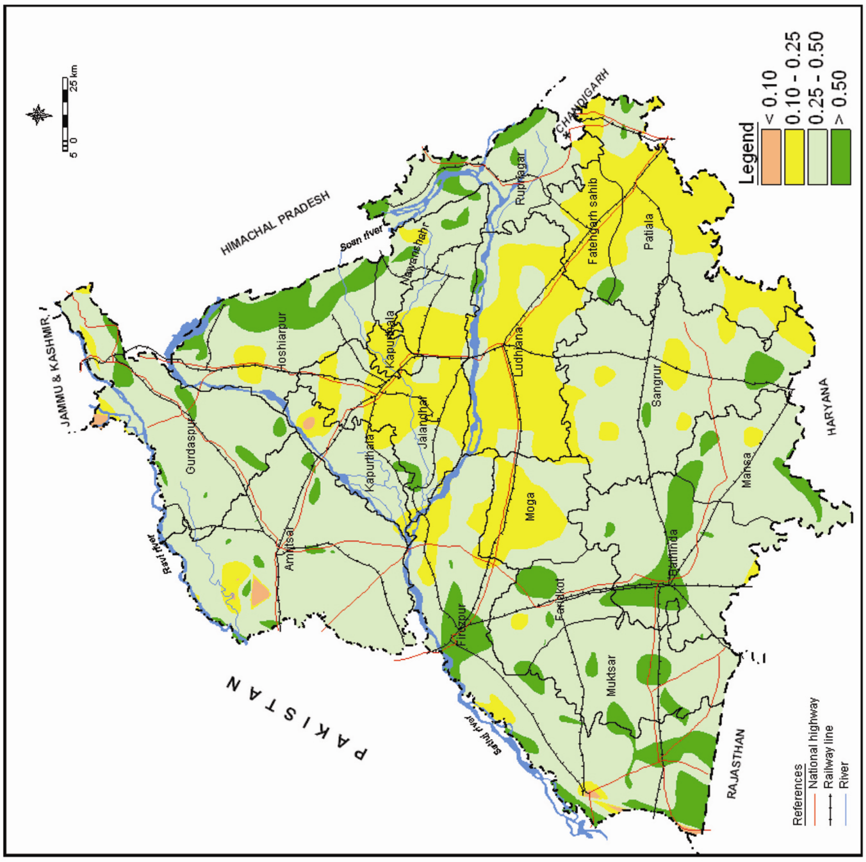

Figure 5. Cover factor map of Punjab.

to minimize soil disturbance. The soil erosion map generated in the study would be helpful for land-use planners and policy makers to adopt the best site-specific best management practices to bring down the soil erosion rates within the tolerable limit.

1. Oldeman, L. R., Global extent of soil degradation. Bi-annual Report. ISRIC, Wageningen, The Netherlands, 1991, pp. 19–35.
2. Scherr, S. J. and Yadav, S., Land degradation in the developing world: implications for food, agriculture, and the environment to 2020, Food, Agriculture and the Environment Discussion Paper, 1996.
3. Maji, A. K., Assessment of degraded and wastelands of India. *J. Indian Soc. Soil Sci.*, 2007, **4955**(4), 427–435.
4. Sharda, V. N. and Dogra, P., Assessment of productivity and monetary losses due to water erosion in rainfed crops across different states of India for prioritization and conservation planning. *Agric. Res.*, 2013, **2**(4), 382–392.
5. Sharda, V. N., Dogra, P. and Prakash, C., Assessment of production losses due to water erosion in rainfed areas of India. *J. Soil Water Conserv.*, 2010, **65**(2), 79–91.
6. Singh, G., Ram Babu, Bhusan, L. S. and Abrol, I. P., Soil erosion rates in India. *J. Soil Water Conserv.*, 1992, **47**, 97–99.
7. Velayutham, M. and Bhattacharyya, T., Soil resource management. In *Natural Resource Management for Agricultural Production in India* (eds Yadav, J. S. P. and Singh, G. B.), 2000, pp. 1–137.
8. Kurothe, R. S., Batta, R. K. and Sharma, J. P., Soil erosion map of Gujarat. *Indian J. Soil Conserv.*, 1997, **25**, 9–13.
9. Kurothe, R. S., Challa, O., Samra, J. S. and Velayutham, M., Assessment of soil erosion in Maharashtra. *Indian J. Soil Conserv.*, 2001, **29**, 133–137.
10. Sikka, A. K. *et al.*, Soil erosion map of Kerala state. *Indian J. Soil Conserv..*, 2003, **31**, 127–130.
11. Yadav, R. P. and Sachdev, C. B., Assessment of soil erosion in Haryana state. *J. Indian Soc. Soil Sci.*, 2008, **56**, 99–105.
12. Yadav, R. P. and Sidhu, G. S., Assessment of soil erosion in Himachal Pradesh. *J. Indian Soc. Soil Sci.*, 2010, **58**, 212–220.
13. Sur, H. S., Singh, R. and Malhi, S. S., Influence of simulated erosion on soil properties and maize yield in north western India. *Commun. Soil Sci. Plant Anal.*, 1998, **29**(17–18), 2647–2658.
14. Wischmeier, W. H. and Smith, D. D., Predicting rainfall erosion losses – a guide for conservation planning. Agriculture Hand book No. 537, USDA, Washington, DC, 1978, p. 58.
15. Wischmeier, W. H. and Mannering, J. V., Relation of soil properties to its erodibility. *Soil Sci. Soc. Am. Proc.*, 1969, **33**, 131–137.
16. Ram Babu, Tejwani, K. G., Agarwal, M. C. and Subhash Chandra, Rainfall erosion potential and iso-erodent map of India. Central Soil and Water Conservation Research and Training Institute, Dehradun, Bulletin No. 2. p. 47, 1978.
17. Renard, K. G., Laften, J. M., Foster, G. R. and Mc Cool, D. K., The revised soil loss equation. In *Soil Erosion – Research Methods* (ed. Lal, R.), Soil and Water Conservation Society, Ankeny (USA), 1994, pp. 105–124.
18. Sidhu, G. S., Walia, C. S., Lal, Tarsem, Rana, K. P. C. and Sehgal, J., *Soils of Punjab for Optimizing Land Use*, NBSS Publ. 45 (Soils of India Series). National Bureau of Soil Survey and Land Use Planning, Nagpur, 1995, p. 75.
19. Anon., *District-wise Area and Production of Crops*, Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India, New Delhi, 1998–99.
20. Singh, G., Ram Babu and Subhash Chandra, Soil Loss Prediction Research in India. ICAR Bulletin No. T-12/ D-9. Central Soil and Water Conservation Research and Training Institute, Dehradun, 1981, p. 70.

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Protein-rich food does not affect singing behaviour and song quality in adult zebra finches, *Taeniopygia guttata*

Neelu Anand Jha and Vinod Kumar*

Indo-US Center for Biological Timing, Department of Zoology, University of Delhi, Delhi 110 007, India

This study investigated whether short-term protein supplement to the seed-only diet during adulthood would impact the production and song features in male zebra finches (*Taeniopygia guttata*). In singly housed adult male zebra finches provided daily with seeds as food without or with 1 g of egg white protein supplement (equivalent to ~0.11 g egg proteins) under 12 h light : 12 h dark condition for 8 weeks, we recorded singing pattern at the beginning and end over 2 days when a female conspecific shared his cage. We found no effect of the egg protein supplement on daily song production, song bout duration and motifs per bout as well as the spectral features of the song, viz. motif duration, amplitude, pitch, goodness, mean frequency, frequency modulation, amplitude modulation or entropy. Perhaps, as sexually selected trait, song quality is not directly related to body metabolism. It is likely that seeds provided met energy requirement for vocalization (song production), and so additional egg white protein supplement did not affect the singing behaviour in adult zebra finches.

Keywords: Bird, food, protein, singing, song, zebra finch.

AMONG Passeriformes birds, male vocalization (singing) is a sexually selected trait for reproductive success, with territorial defence and mate attraction being its primary functions[1]. Male singing, as discernible by the song pattern, is species-specific[2], condition-dependent[3] and signals conspecific female about his physical condition[4]. Interestingly, and importantly, female presence can affect vocal learning and improvization of the male song[5] and a male song can have larger number of introductory notes and frequently repeated motifs when directed towards the female[6].

Among ecological factors, food has been shown to have significant effects on male singing. Pied flycatchers, *Ficedula hypoleuca*, sang more number of songs[7], and black-capped chickadees, *Poecile atricapillus*, increased dawn singing[8], when they were fed daily with 20 and 30 mealworms respectively. Similarly, Australian reed warblers (*Acrocephalus australis*) sang more on days when fed with 30 g of live blowfly maggots[9], and silvereyes (*Zosterops lateralis*) sang for a longer duration when fed

*For correspondence. (e-mail: drvkumar11@gmail.com)