Enhancing soil productivity through biological amendments

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WATER BALANCE IN RAINFED AREAS

- Precipitation : 100
- Evaporation : 30 – 50
- Transpiration : 15 – 30*
- Runoff : 10-25
- Percolation : 10-30

* Could be 5% in poor/degraded soils

Soil Productivity

- Soil's capacity to produce a certain yield (kg ha^{-1}) of crops or other plants with optimum management (soil and non-soil factors).
- Management - planting date, fertilization, irrigation schedule, tillage, cropping sequence, and pest control.
- Influenced by weather and the nature and aspect of slope, which greatly affect water runoff and erosion.

Productivity Index

$$PI = \sum_{i=1}^{n} (A_i \times C_i \times D_i \times WF_i)$$

- Where,
- PI is productivity index, varying from 0 to 1
- *i = 1, 2, ….*
- *n stands* for different soil layer
- *Ai is the suitability index of available* soil water content in the *ith layer*
- *Ci is the suitability* index of soil bulk density in the *ith layer;*
- *Di is the* suitability index of the soil pH in the *ith layer;*
- *WFi is the* weight of the *ith layer.*

Soil Loss Tolerance

The PI could estimate the tolerable rate of soil productivity loss using the approach to evaluate

Soil Loss Tolerance, $T = \delta - H$

Where, δ

δ is permissible soil productivity loss (%), it varies between 0.05 and 0.10 (5% to 10%)

H is sustainable land use for maintaining productivity in horizon (years), it could be assumed to be 100 to 200 years

Erosion Risk Index

$$ERI = \frac{\eta}{10(1-\alpha)}$$

- Where,
- *α* evaluates the soil runoff potential in function of soil structure, soil particle sizes, and coarse fragments
- η evaluates the impact of the terrain slope (modal slope) on erosion risk under different rainfall aggressiveness
- ERI has a value between 0 and 1, with 1 corresponding to a land unit that presents the highest potential conditions for inducing water erosion processes

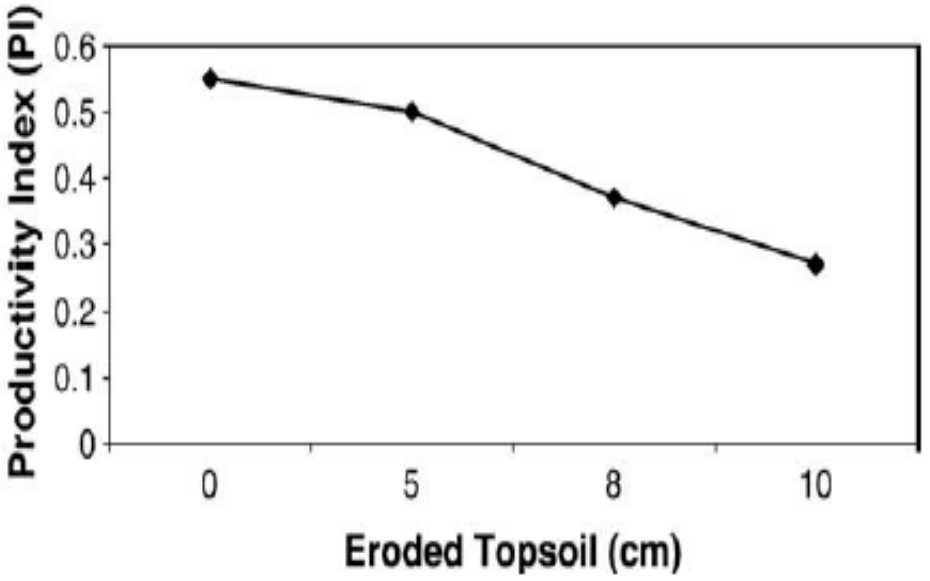
Ranking the Soil PI and ERI

PI or ERI	Soil productivity or Erosion risk
≤ 0.10	Low
0.11–0.30	Moderate
0.31–0.50	High
> 50	Very high

- The PI and the ERI are used to classify the lands for soil conservation priorities, for conservation requirements, and for alternative land uses.

Soil Erosion Vulnerability

- Soil erosion vulnerability is the rate of changes in productivity, measured by changes in PI values per unit of removed soil by erosion.



Land classification system for soil conservation on steeplands

		Erosion Risk Index (ERI)				General land use
		≤0.10 (low)	0.11–0.30 (moderate)	0.31–0.50 (high)	>0.50 (very high)	
Soil Productivity Index (PI)	≤0.10 (low)	Reserve lands (R) (4th priority conservation treatment)		Critical lands (C) (2nd priority conservation treatment)		Permanent vegetation Agroforestry Special crops/agroforestry
	0.11–0.30 (moderate)					
	0.31–0.50 (high)	Sub-critical lands (S) (3rd priority conservation treatment)		Super-critical lands (P) (1st priority conservation treatment)		Semi-intensive agriculture
	>0.50 (very high)					Intensive agriculture

Northwest Frontier Region of Pakistan

- Arid and semi-arid climate
- Land degradation by periodic floods and nutrient mining
- Declined soil productivity due to erosion
- Agriculture is not a profitable activity
- Non-sustainable farming and livelihood
- Prospects ?

Biological Amendments

- Improve the physical, chemical and biological characteristics of soil
- Include green / farmyard manure, compost plant residues, organic wastes, and microbial inoculants, which build organic content and increase the soil's capacity to circulate nutrients, air and water.

Biological Amendments

- In watersheds, they reduces the cost of purifying drinking water, and soils have substantially less erosion and greater water holding capacity.
- Enhance the biological activity in soil.
- Stabilize the soils against erosion and floods, detoxify ecosystems, and counteract climate change by restoring "soil's capacity for carbon sequestration".

Scientific Precedents

- Soil erosion is the most widespread form of soil degradation in the world and its greatest impact on C storage may be in affecting soil productivity. Management practices that help control erosion can improve productivity and promote sustained production (Gregorich et al., 1998)

Scientific Precedents

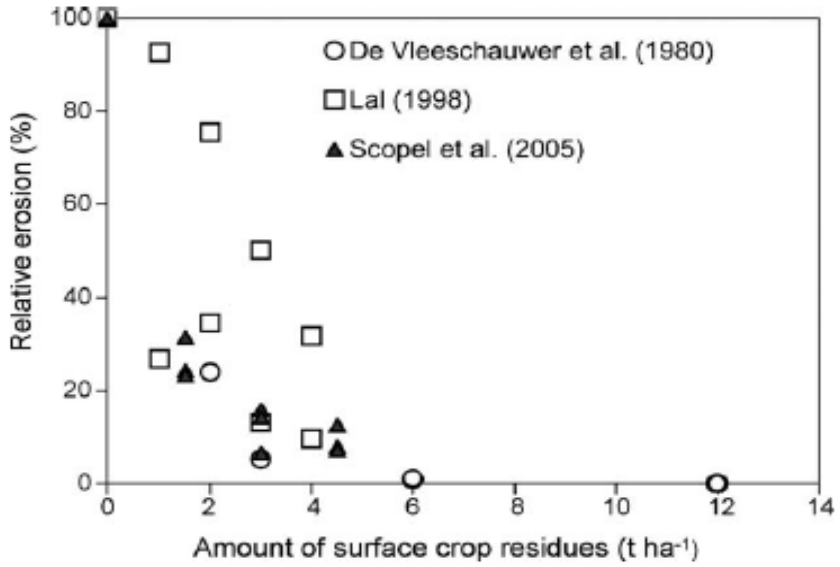
- In Alberta, application of 24 Mg ha-t of cattle manure increased wheat grain yield by 0.58 Mg ha^{-1} on severely eroded soil, 0.25 Mg ha^{-1} on moderately eroded soil and 0.16 Mg ha^{-1} on non-eroded soil compared to the non-manured soil (Larney & Janzen, 1997).

Scientific Precedents

- The microbially-treated (Aspergillus niger) dry olive cake proved to be an effective amendment for improving the soil quality which, in turn, enhanced the success of revegetation with mycorrhizal *D. pentaphyllum* (leguminous shrub) seedlings (Alguacil et al., 2008).

Scientific Precedents

- There is a clear relationship between retention of mulch and reduction of runoff and soil losses by erosion (Lal, 1998a; Erenstein, 2002).



Scientific Precedents

- However, on very steep slopes, mulch retention alone will be insufficient to control erosion and other physical control measures such as contour bunds are needed to reduce the slope length (Roose and Barthes, 2001).

NEEDED APPROACH

- Better Land Husbandry
- Moving from Soil conservation to Land husbandry
- Improve SOM
- Tap Synergies of crop-livestock- tree systems

SOIL MANAGEMENT

- Soil cover through cover crops and mulching (reduced erosion and evaporation)
- Organic matter addition (OM enhances water holding capacity)

CROP RESIDUES MAINTAINED ON THE SOIL SURFACE

EARTHWORMS (SOIL FAUNA)

MYCORRHIZA (SOIL FLORA)

Conclusions

- Erosion reduces the soil productivity by affecting the soil properties and soil depth.
- The Soil Productivity Index (PI) can be used as a criterion of tolerance of soil loss due to soil erosion.
- Soil Productivity and Erosion Risk Indices (ERI) allow classifying general land use areas in view of soil conservation systems.

Conclusions

- In the Northwest Frontier region, on slightly eroded soil, intensive agriculture is possible; whereas, on severely eroded soil only special crops or agroforestry can be grown. Moderately eroded soil can be used for semi-intensive agriculture.

- Biological amendments hold great promise for enhancing soil productivity in eroded areas.