Environmental Cost of using top-soil for brick making – a case study from India

(MoEF, GoI project)

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Problem/Issue?

- Removal of topsoil for brick-making is ↑ fast due to ↑ urbanization & industrialization in many developing countries.
- Unfortunately, brick kilns are mostly situated on fertile agricultural land, as brick mfrs need **silty clay loam to silty clay soils** with good drainage conditions.
- Urbanization and brick mfrs requirement → change in land use pattern → Good agricultural land turning into agriculturally unproductive lands around growing cities.
- Apart from this, two important concerns arise
  - Often, farmers are forced to sell soil for brick-making because their neighbors have sold soil → leaves 4-6' deep gap in surface levels between those who have sold soil vs. those who haven't.
  - Excessive depth over which the soil is removed above the agreed depth of soil extraction → land unsuitable for agriculture..

Gap in the surface level for two farmers in Tuticorin region

Soil extraction above agreed depth

Soil extraction above agreed depth (Chennai)

Focus of the paper

- Main focus of the study is to quantify the agricultural impacts of topsoil removal for brick-making.
- -ve impact of topsoil removal is quantified in terms of
  - the reduction in agricultural output (**Productivity Change approach**) and
  - the cost of replacing the lost nutrients (**Replacement cost approach**).
- Quantification for Tamil Nadu, a Southern State of India.
- State has highest rate of urbanization
  - Against TN's urbanization rate of 44%,
  - AI average - only 27.8%.
- Project guidelines

Quantification - how?

- A survey of 100 farmers each is carried out in two regions – Chennai (Cooum river basin) and Tuticorin (Tamirabarani river basin).

- Only criteria - farmers should fall within 100 km radius of Thermal Power Plants – **mandated by Supreme Court order to use Fly ash for brick making**.

- Apart from the survey, 60 soil samples – 30 from each region - are analyzed from both types of fields i.e.,
  - the fields sold / leased land for brick making, and
  - virgin fields not exposed to excavation by brick mfrs.

Methodology

- Agricultural impact of topsoil removal for brick-making is two fold, viz.,

  a) costs incurred in leveling the field and/or mitigating hardpan problem by applying tank silt; &

  b) loss of soil nutrients.

- Former - directly observable;
- Latter are indirect – hence indirect methods – RCA, PCA.

❖ Nutrient loss $\rightarrow \downarrow$ crop yield

(unless all critical nutrients are replaced through application of organic matter and fertilizers).

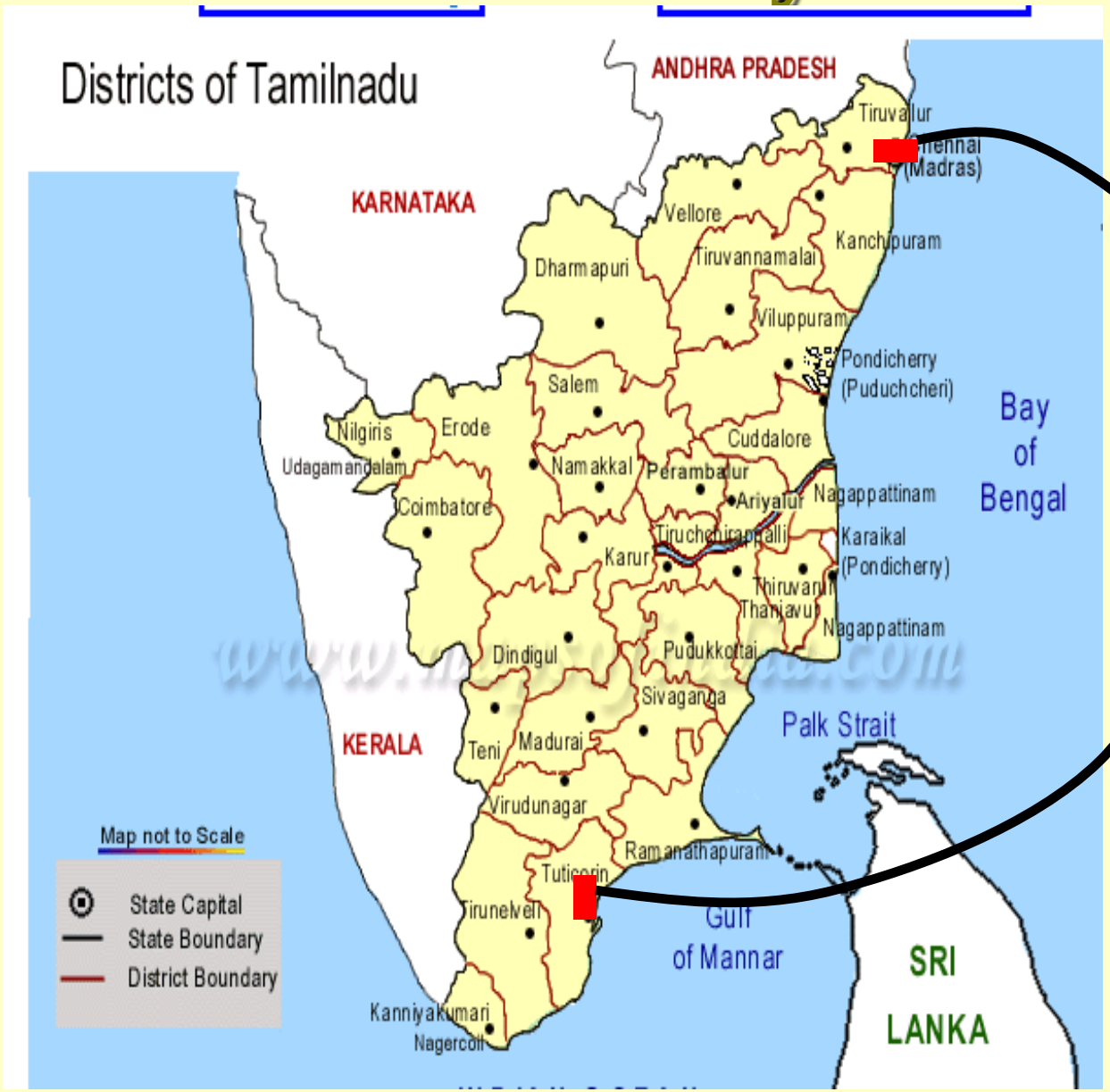
Sampling

- Poonamalle taluk (Thiruvalloor dist.) in North T.N. and Sri Vaikuntam taluk (Tuticorin dist.) in South T.N. selected.
- Taluks Selection - purposive - both fall within a radius of 100 Km from 2 TPPs i.e., North Chennai and Tuticorin.
- In each taluk - survey numbers list (& village name) from where topsoil has been leased/given to brick mfrs obtained from respective collector's office, from which 5 villages were chosen at random.
- 20 farmers selected at random from each of 5 villages - farmers post-stratified into sellers & non-sellers of soil for brick-making.

$\Rightarrow$ 100 farmers - selected from each region.

- Data on land holding pattern, irrigation sources, area & depth of soil sold, income from sale of soil, crops cultivated in last 3 years, inputs applied, yield & returns from crop production - obtained through a **structured, pre-tested questionnaire**.

Study area



Study Areas - Location

Analysis

Replacement cost approach

- In each region 30 soil samples – 15 each from affected & unaffected plots analyzed to quantify differences in 3 nutrients- N, P, K, micro-nutrients - Fe, Zi, Cu and Mn & organic matter content of the soils.
- Differences in soil nutrient status between affected and unaffected plots were valued using current market prices of these nutrients.

Productivity change approach (PCA)

- Basic premise – topsoil mining → yield loss → ↓ income.
- Moreover, removal of topsoil not only → loss of nutrients but also → some important physical properties of the soil – such as water holding capacity, porosity etc.
- which can't be replaced by fertilizer application & difficult to quantify using RCA – but such loss impacts productivity directly.
- In PCA, the production function is specified in Cobb-Douglas form.

PCA contd.

$$\ln y = \ln a + b_1 \ln N + b_2 \ln P + b_3 \ln K + b_4 \ln FYM + b_5 \ln HLAB + b_6 SDUM$$

where y = yield of crops in kg/acre

N, P and K = nitrogen, phosphorus or potash kg/acre

FYM = farmyard manure (tonnes/acre)

HLAB = human labour in man-days/acre

SDUM = dummy variable = 1 for plots selling soils; and 0 otherwise.

- Estimated coefficient of dummy variable (b_6) for soil mining (SDUM) helps to quantify the loss in change in productivity due to loss of topsoil.

Yield loss due to soil mining = b6 x Mean yield of crop.

Land holding & Cropping pattern

- Av. size of operational holding ≈ 2.40 acres (1 acre = 4050 sq. m) in North region & 3.00 acres in South region
- Incidence of tenancy meager ≈ 10% holdings are leased.
- Irrigation:
  - Canals & system tanks linked to Tamirabarani river - in South
  - Tanks and bore-wells in North study area.
- ≈ 70% (South) - 80% (North) area under wetland cultivation.
- **Predominant cultivation - Wet season paddy**
- **North** - Paddy-Groundnut-Fallow & Paddy-Paddy-Fallow
- **South** - Paddy-Paddy-Fallow & Paddy-Banana-Banana

NOTE: In South, Coconut (perennial) grown by some farmers especially along irrigation channels - very little application of man-made inputs such as fertilizers

Cropping Pattern

(Seasons - June to Sep; Oct to Jan; Feb. to May).

- **1st season - Groundnut** accounts ≈ 75% of area cultivated in **North** while **banana** accounts for little over 75% of the area in the **Southern** region.
- **Paddy - major crop in 2nd season** in both regions (≈ 85% of the cultivated area in North < 53% in South).

NOTE: Less share of paddy in South – as banana - an annual crop occupies land for ≈ 10 months → ↓ land available for paddy.

Table: Sale of soil for brick making (mean for farms that sold soil) (1US$ = Rs. 44)

Details	North (47)			South (55)			Mean of two regions
	Min.	Max.	Mean (SDev.)	Min.	Max.	Mean (SDev.)	
Av. Land area in which soil was sold (acre)	0.10	3.50	1.18 (1.31)	0.15	2.75	0.95 (0.82)	**1.06**
Depth of soil sold (feet)	2.00	6.00	3.47 (2.12)	1.75	5.00	2.82* (0.97)	**3.15**
Quantity of soil sold (acre-feet)	0.40	14.00	4.10 (2.43)	0.25	11.50	2.68** (1.16)	**3.34**
Av. income from sale of soil (Rs./farm)	7000	220000	60,863 (29,591)	5500	185000	47927** (21,564)	**54,395**

- Why higher income in North?
  - More demand for soil & higher land value.

Reason for sale & perceived quality

	Reason	North	South	Mean
1	Level the land	56.52	38.18	**47.35**
2	Urgent need for liquidity	26.09	32.73	**29.41**
3	Poor quality of topsoil	13.04	20.00	**16.52**
4	Not interested in active agriculture	4.35	9.09	**6.72**

	Perceived changes due to Sale of Top-soil	Quality Change		Yield Change	
		North (N-100)	South (N-100)	North (N-100)	South (N-100)
1	**Decline**	**23.10**	**27.27**	**23.40**	**25.45**
2	Improvement	19.15	18.18	17.02	10.91
3	**No change**	**51.06**	**45.45**	**53.19**	**54.55**
4	Land abandoned after sale/sold land to brick mfr	6.38	9.09	6.38	9.09

Results - Soil fertility- mined vs. unmined plots

	Topsoil not removed (N= 30) (Average)	Topsoil removed (N=30) (Average) (% change)
Major nutrients (kg/acre)		
Nitrogen (N)	**32.04**	**20.75 (35.23)**
Phosphorous (P)	**4.55**	**3.18 (30.16)**
Potash (K)	**66.49**	**52.77 (20.63)**
Micronutrients (kg/acre)		
Copper (Cu)	**1.99**	**0.95 (52.26)**
Iron (Fe)	**30.64**	**16.87 (44.94)**
Zinc (Zn)	**1.16**	**0.47 (59.48)**
Manganese (Mn)	**14.01**	**8.73 (37.69)**
Organic matter	**1700.40**	**1417.04 (16.66)**

- Topsoil in Southern region - more fertile in N & K before mining
- Impact of topsoil removal higher in North region (loss in N & K.)
- With Micro-nutrients - % reduction varying from 35% for Mn in North to ≈ 63% for Zn in South.

Results: RCA – Cost of replacing nutirents

- Costs of replacement of micronutrients such as Fe and Mn > other nutrients – due to a) higher losses; and b) higher market prices.
- Loss in organic matter - highest in physical terms while its monetary value was in the range of Rs. 97 – 130/ acre.
- Among major nutrients, average cost of replacement of
  - N - Rs. 123/acre (≈ **2.8 $**)
  - K - Rs. 100/acre (≈ **2.3 $**) and
  - P - Rs. 28/acre (≈ **0.6 $**).
- Total cost of replacing nutrients lost due to soil mining
  - Rs. 1218/acre in Northern region and
  - Rs. 1297/acre in Southern region
  - with inter-regional average - **Rs. 1267/acre (≈ 29$)**.
- Meager compared to income realized by farmers thru sale of soil.
- i.e, why farmers resort to sale of topsoil at a depth of ≈ 3 feet.

PCA – Impact of topsoil removal on yield

- Topsoil removal → deeper layers of soil under cultivation.
- Despite remedial measures like additional fertilizers, tank silt & farm-yard manure, crop yield ↓ at least initially.

(due to inadequate organic matter content & ↓ microbial activity in deeper layers - lack of humus & sunlight).

- Over time, deeper soil layers gain higher fertility status & desirable physical properties with slow addition of organic residues, inorganic fertilizers, water and sunlight.

⇒ One should not select the plots from which soil was removed much earlier.

PCA – Impact of topsoil removal on yield

- Present study selects those affected plots from where soil was removed not before six years from latest crop year.
- Average difference in yield between plot with & without topsoil removal is found
  - 50 kg/acre for paddy
  - 25 kg/acre for groundnut
  - No difference for banana (yield = no. of bunches)

(banana from mined plots - small in size ⇒ lower prices → ↓ income).

- Reduction in income due to selling soil is found to be
  - highest in case of banana (≅ Rs. 2,700 /acre ≈ **61$**)
  - groundnut – Rs. 1,177 /acre (≈ **27 $)** and
  - rice - Rs. 500 /acre (≈ **12 $)** in that order
- ↓ income is higher in high value / commercial crops

Comparison of crop yield & returns in farms – sold soil & did not sell soil

Details	Farmers who didn't sell soil			Farmers who sold soil			Loss in net returns (% loss in net Returns)
	Yield	Total returns (Rs./ acre)	Net returns (Rs./ acre)	Yield	Total returns (Rs./ acre)	Net returns (Rs./ acre)	
Paddy (Yield in kg./acre)	1801	10,521	3,294	1749	10,262	2,798*	496 (15.06)
Banana (Yield in number of bunches / acre)	798	35,830	22,860	794	33,348	20,163**	2,697 (11.80)
Groundnut (Yield in kg/acre)	603	10,625	5,483	578	9,756	4,306**	1,177 (21.47)

NOTE: Difference in yield could be due to other factors of farm prod^{n} $\Rightarrow$ need for Production function analysis.

Yield & income losses due to topsoil mining

(Dummy for soil mining statistically significant for all crops

⇒ soil mining → significant ↓ in crop yield.

δ(Crop Income) = Coefficient x Mean yield x price of crop output /kg.

	Crop (1)	Regression coefficient for dummy representing soil mining (2)	Mean yield (3)	Yield loss due to soil mining (2 x 3) (4)	Price of crop output (Rs/kg) (5)	Income loss due to soil mining (4 x 5) (6)	Total Income Loss for discount rate of 5% (7)	Total Income Loss for discount rate of 8% (8)
1	Paddy (North)	0.1211	1812	219.43	6.00	1316.60	10674.76	9541.253
2	Groundnut (North)	0.1275	590	75.23	16.87	1269.00	10288.83	9196.301
3	Paddy (South)	0.0978	1738	169.98	5.85	994.36	8062.094	7206.015
4	Banana (South)	0.126	11940	1504.44	1.95	2933.65	23785.51	21259.83

Economic Impact of top soil mining (Inter-regional average)

- Total cost of replacing nutrients, leveling the land and applying tank silt ≅ Rs. 2,475/acre (≈ **56$**) (RCA).
- Total income loss due to yield reduction caused by topsoil removal ≈ Rs. 3,250/acre/year (≈ **74$**)(PCA).

∴ ≅ Rs. 780 (≈ **18$**) difference between two approaches.

NOTE: Difference seems reasonable - as the removal of topsoil → loss of certain unquantifiable, qualitative properties of topsoil - not reflected in RCA but still lead to yield loss.

Economic impact of topsoil/brick-earth removal for brick-making (Rs./acre)

	Details	North	South	Average
1	Application of tank silt for leveling and overcoming the hardpan problem	1,132	1,301	1,217
2	Cost of replacement of soil nutrients	1,219	1,298	1,268
3	**Total cost of replacement, tank silt application and leveling (1+2)***	**2,351**	**2,599**	**2,475**
4	**Economic value of yield loss due to soil mining #**	**20,963**	**31,847**	**26,405**

Remedial Measures Taken

- To offset -ve effect of topsoil removal on soil quality & crop yield most farmers resorted to: application of tank silt, high dose of inorganic fertilizers in the ensuing few seasons and / or farm yard manure and green manure.

- **Leveling soil and overcoming hardpan of soil layers -** ≅ 10% of the farmers resorted to application of tank silt to solve problem → Av. cost of Rs. 1,217/acre (**≈28$**).

- **Restoring organic matter** – using farmyard manure ≅ 45% farmers used → Av. cost of Rs. 435/acre (**≈10$**) (NOT an out of pocket expenses, as available within farm)

- **Applying high dose of inorganic manure/fertilizer** ≅ 25% farmers → expenditure of Rs. 143/acre (**≈3$**).

Cost-Benefit comparison

- Small fraction of total income from sale of soil on remedial measures to restore the soil fertility.
- Out of the average revenue of Rs. 54,000/acre **(1227 $)** from the sale of soil only about Rs. 1,800/ acre **(41 $) (≅ 3.3%)**. has been spent on remedial measures to restore soil fertility

WHY expenditure so low?

- Most farmers perceived - soil is infinitely renewable resource both in terms of quality and quantity and hence there is nothing wrong in selling the soil.

Concluding Remarks

- Crop yield loss due to topsoil removal has been much less than expected in the regions.

  Why?

- Both regions endowed with very deep vertisols, (more fertile soils) ⇒ deeper layers become suitable for crop prod^{n} with suitable remedial measures at low cost.

- 85% of farmers have done that.

Why farmers are selling the land/top-soil?

- ↓ agriculture profitability associated with higher risks,
- ↑ labor cost for agricultural activities esp. around cities
- tendency among youth to move away fm agriculture

⇒ ↓ agriculture importance → decision to sell soil and / or land to the brick-kilns.

Concluding Remarks

- In the long run, the opportunity cost of selling top soil for brick making is likely to increase as good quality soils for agriculture become more and more scarce.
- Need for appropriate policy interventions
  - to discourage the sale of topsoil for brick making and
  - to find alternative sources of raw materials for brick making.
- **Utilization of fly-ash from TPPs for brick making - a win-win option as it would reduce pollution caused by free disposal of fly-ash and reduce the demand for topsoil for brick making.**

Thank you