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Agro-geotextiles: Enhancing sloping rainfed arable land productivity in the north-western Himalayan region

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Agro-geotextiles refers to any textile or fabric which is used to mitigate soil related constraints in the field. They stabilise soil by enhancing soil structure, reduce soil erosion that in return increase water infiltration, reduce soil loss and ultimately help in sustaining crop productivity. The article presents the possibility of using conservation tillage (CT) based Arundo donax *agro-geotextiles (AD-AGTs) to increase cropping intensity on slopping rainfed arable land in north-western Himalayan region of India. The rigid leaves and robust stem/culm are utilised in the production of AD-AGTs. This grass has accelerated growth and enhanced density, leading to a coarser surface and less soil surface runoff. It is an alternative, practical, temporary, and economically viable option for soil and water conservation technologies in the region.*

Keywords: *Arundo donax*, Catch crop, Conservation tillage, Soil conservation

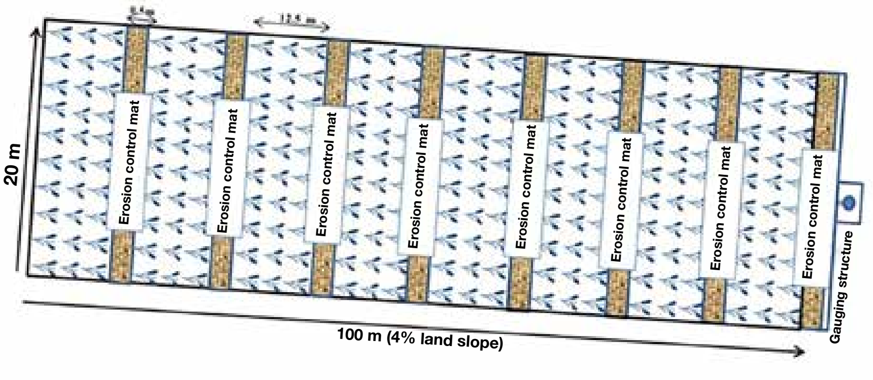
SOIL and water conservation techniques are essential for the control of soil erosion and the support of land management initiatives in order to achieve the United Nations Sustainable Development Goal pertaining to Land Degradation Neutrality (LDN) challenges. Globally, a substantial proportion of both arable and non-arable lands are subjected to moderate to severe erosion, which exacerbates economic and ecological vulnerabilities. It is anticipated that the impact of water erosion caused by concentrated discharge flow will increase considerably in response to global climate change, as future projections suggest that extreme rainfall events will become more frequent and intense.

In June 2013, extreme rainfall events occurred over three consecutive days, with intensities exceeding 80 mm/h and a staggering 350 mm recorded in a single day on the 17th June. This unprecedented rainfall, totaling 750 mm, resulted in severe flooding, leading to significant loss of human and animal life, as well as posing a threat to the Himalayan ecosystem. Annual soil loss limits exceeding permissible limits were observed in the study area of Dehradun, even with the implementation of best

Impact of extreme rainfall events with increased frequency and intensity (*Source*: USDA Natural Resources Conservation Service)

Vegetative barriers (Potential source of rodent menace)

Arundo donax (Giant reed) grass



Layout of *Arundo donax*-AGT on a 0.5 m vertical-intervals

management practices (BMPs) such as cereal and legume intercropping, vegetative barriers, conservation bench terraces, and the combined use of inorganic and organic plant nutrients, along with *in situ* live green manuring and tillage and mulch practices. The efficacy of aromatic grass-based vegetative barriers, grass-hedges, and filters in the conservation of water and soil has been demonstrated. Nevertheless, farmers exhibited a perceptible reluctance to implement this technology, primarily because of the substantial land area that these barriers require on a year-round basis. Not only does this impede agricultural practices (including tillage, cultural operations, and harvesting), but it also increases the likelihood of rodent infestations in cereal crops.

In this context, it is essential to develop alternative, practical, temporary and economically viable soil and water conservation technologies, such as the prompt application of agro-geotextiles (AGTs) derived from locally available biomass residues like *Arundo donax* (AD), which presently lacks economic value, exemplifying a wealth-from-waste strategy. The utilisation of these AGTs in conjunction with conservation agricultural (CA) approaches is termed conservation agriculture plus. This method can markedly reduce surface runoff and consequent soil erosion along with nutrient depletion, so aiding in the retention and conservation of runoff water, which is typically considered a vital resource inside soil strata for future use. This practice is known as the green water approach. Sloped farming fields contribute to the loss of soil and nutrients, resulting in a decline in the quality of surface water globally.

Arundo donax agro-geotextile technology based on conservation tillage

The dominant cropping system of the north-western Himalayan region encompasses rainfed rainy season maize from mid-June to mid-September and winter (*rabi*) season wheat from mid-November to mid-April, covering approximately 0.6 million hectares. The biomass incorporation of a legume crop like green peas (*Pisum sativum* var. *hortense*) as an autumn catch crop (mid-September to mid-December) serves to diversify crops and enhance profitability. This practice will not only boost cropping intensity but also improve organic carbon of soil (SOC) and increase the soil moisture retention capacity, thereby contributing to a reduction in soil erosion. However, under the rainfed conditions, there is considerable hesitation among farmers to cultivate green pea as a catch crop in-between maize and wheat crops. This reluctance stems from the green pea tendency to extract conserved soil moisture, which subsequently restricts the conserved soil moisture used for the germination and growth of wheat seedlings. Furthermore, the planting of the subsequent wheat crop is also postponed by one month, which restricts its productivity.

While synthetic geotextiles are

Table 1. Details of agronomical practices of the maize-pea-wheat crop rotation

Agronomic practices	Timing/Stage	Details/Rates
	Maize (zero-till)	
Herbicide (tank mix) application for weed control	Pre-emergence (1–2 days after sowing)	Atrazine @ 1.0 kg a.i./ha, Pendimethalin @ 1.5 kg a.i./ha, Glyphosate @ 1.5 kg a.i./ha
Top-dressing of urea	Seedling stage (10–15 days after sowing)	Urea @ 87 kg/ha
Top-dressing of urea	Knee height (30–35 days after sowing)	Urea @ 87 kg/ha
Top-dressing of urea	Tasseling (45 days after sowing)	Urea @ 87 kg/ha
Fall armyworm control	On symptom appearance	Spray of Chlorpyriphos @ 2 mL/L water or Neem oil @ 5 mL/L water
	Green pea (reduced till)	
Basal dose of DAP	At sowing (basal)	100 kg/ha
	Wheat (reduced till)	
NPK (12:32:16) application	At sowing (basal)	NPK @ 188 kg/ha
Top-dressing of urea	Crown root initiation (20-25 days after sowing)	Urea @ 90 kg/ha. Timing coincides with first winter rain
Herbicide (tank mix) application for weed control	Post-emergence (35–40 days after sowing)	Metsulfuron-methyl @ 4.0 g a.i./ha + Clodinafop-propargyl @ 60 g a.i./ha
Top-dressing of urea	Booting stage (60 days after sowing)	Urea @ 90 kg/ha. Timing coincides with second winter rain
Disease control (prophylactic fungicide)	Flowering stage (90 days after sowing)	Spray Propiconazole or Tilt @ 0.5 mL/L water

Zero-tilled maize planted in-between 15 cm tall wheat stubbles along with *Arundo donax* ago-geotextiles (AD-AGT)

Strips of 0.5 m wide AD-AGT of 5 cm thickness placed in between the maize rows

Table 2. Crop productivity and resource conservation potential of conservation tillage-based maize-green pea-wheat rotation

Attributes	Without *Arundo donax* agro-geotextiles	With *Arundo donax* agro-geotextiles
Wheat equivalent yield (t/ha)	6.28	14.08
Runoff* (%)	27.1	8.5
Soil loss (t/ha)	12.56	0.87
SOC stock (t/ha)	22.74	27.87

* Monsoon rainfall~1,200–1,400 mm, SOC: Soil organic carbon.

prevalent in the commercial sector, those made from locally sourced organic materials prove to be quite effective for erosion control and promoting vegetation growth. Given that AD green biomass naturally occurs in torrent-beds adjacent to agricultural fields, applying this biomass to the soil represents a cost-effective method.

Arundo donax (Giant reed) grass

This AD grass is cut when its culms/stover attain a height of 5–6 m and yield lush green, sturdy leafy biomass. The rigid leaves and robust stem/culm are utilised in the production of AD-AGTs employing locally available resources. This grass has accelerated growth and enhanced density, leading to a coarser surface and less soil erosion. Biodegradation during maize harvest and its subsequent integration into the soil by tillage supplies nutrients and carbon, hence promoting crop growth and improving SOC, which eventually improves soil aggregate stability. The current AD management strategies rely on seasonal cutting in affected torrents; however, the resultant biomass waste is poorly managed, creating challenges for these waterbodies while also offering an opportunity to transform the waste into a resource like AGT for soil conservation, thus ensuring sufficient treatment to curb its proliferation. In India, it is employed solely for the manufacture of thatches or roofing materials for huts. Animals refrain from feeding on it due to its serrated leaves.

Field trials on 4% field slopes were conducted at ICAR-Indian Institute of Soil and Water Conservation, Dehradun on no-till rainy season maize followed by reduced till autumn sown green pea and winter sown wheat crops during 2017 to 2023. Study location has sub-humid moist climate and silty-clay loam soils.

Recommended rates of N:P:K for maize, pea and wheat applied as 120:00:00 kg/ha through urea, 18:46:0 kg/ha through di-ammonium phosphate (DAP) and 90:60:30 through urea, DAP and NPK combination, respectively. Those farmers who are interested in organic farming, can apply well rotten farmyard manure, compost,

Table 3. Details of cost of cultivation of maize-pea-wheat crop rotation with the application of agro-geotextiles on a 4% slopped field.

Agronomical practices	Expenditure details (₹/ha*)
Maize	
Maize seed 25 kg/ha	5,000
Planting of maize crop	2,000
Pre-emergence weedicides	
Atrazine @ 1 kg a.i.	700
Pendimethalin @ 1.5 kg a.i.	1,500
Glyphosate @ 1.5 kg a.i.	850
Weedicide spray	400**
Cutting and emplacement of AD-AGT	12,000
Urea 260 kg	1,560
Top- dressing of urea	400
Chlorpyriphos 1 L	630
Spray of chloropyriphos	200
In situ weed mulching	4,000
Harvesting and peeling of maize cobs, cutting of maize stover, etc.	15,200
Threshing of maize and cleaning of grains	3,000
Total	47,440
Green pea	
Pea seed @ 100 kg/ha	15,000
Fungicide for seed treatment	490
DAP @ 100 kg/ha	2,700
Field preparation and sowing	6,000
Picking of pods	14,000
Total	38,190

Agronomical practices	Expenditure details (₹/ha*)
Wheat	
Wheat seed @ 120 kg/ha	5040
Urea @ 180 kg/ha	1080
NPK (12:32:16) 188 kg/ha	5640
Fungicide for seed treatment	588
Field preparation and sowing	4500
Top-dressing of urea	400
Post-emergence weedicides	
Metsulfuron-methyl @ 4.0 g *a.i.*	300
Clodinafop-propargyl @ 60.0 g *a.i.*	575
Weedicide spray	400
Fungicide- propicanazole	250
Fungicide spray	400
Harvesting of wheat	2500
Threshing of wheat	2500
Rental value of land for one year	30,000
Miscellaneous expenditures	5000
Total	59,173
Gross total (Maize +Pea +Wheat)	144,803
Interest on total expenditure @ 9%	13,033
Gross total of all the expenditures	157,836

* 1 ha= 12.5 Bigha or 50 Nali; ** One manpower = ₹ 400.

Table 4. Details of economics of maize–pea–wheat crop rotation with the application of agro-geotextiles on a 4% slopped field

Particulars	₹/ha
Direct profits (Market price method)	
Maize grain @ 3,800 kg/ha	74,556
Maize stover @ 4,500 kg/ha	4,500
Green pea pods @ 2,000 kg/ha	60,000
Wheat grain @ 3,500 kg/ha	70,525
Wheat straw @ 5,250 kg/ha	52,500
Total	262,081
In-direct benefits (Supporting ecosystem services)	
Reduced cost of field preparation in maize	2,500
Runoff minimisation in maize (cost replacement method)	1,43,550
Soil loss minimisation in maize (cost replacement method)	2,121
Nutrient loss minimisation in maize (cost replacement method)	440
Soil organic carbon sequestration (based on carbon credit)	3,321
Soil fertility improvement (cost replacement method)	1,097
Saving of N due to pea biomass incorporation	300
Total	153,329
Total Benefits (A+B)	415,410
Total Expenditure (₹/ha)	157,836
Net profit excluding ecosystem-services (₹/ha)	104,245
Economic efficiency (₹/ha/day)	316
Net profit including ecosystem-services (₹/ha)	257,574
Employment generation potential (Mandays/ha/year)	138

In-situ live weed mulching in-between maize rows at 30-35 DAS

vermi-compost, etc. Preceding crop of wheat should be harvested 15 cm above the ground level to maintain standing/vertical stubbles which will prevent runoff velocity during monsoon season.

Maize varieties like 'Vivek Maize Hybrid-45' or 'Kanchan' should be directly planted either using manually operated seed drill or behind the furrows of wooden plough or a multi-crop planter across the field slope (60 cm × 20 cm spacing) in between 15 cm standing wheat stubbles by the mid-June at the time of commencement of the sufficient rainy season rains. Strips of 0.5 m or 50 cm wide (e.g. eight number in length of 100 m field of 4% slope for the 0.5 m vertical intervals) AD-AGT of 5 cm thickness should be emplaced in between two maize rows planted at 60 cm spacing.

A manual grass cutting should be performed in maize at 30–35 days after sowing (DAS), and the resulting biomass can be utilised as a mulch between two maize rows (*in situ* live weed mulching).

After the harvest of maize crop in middle of September, incorporate all the maize stubble, weed biomass, and AD-AGT biomass into the soil by reduce tillage implements like disc harrow. Next, prepare land for 60-day rainfed green pea var. 'Arkel' seeding. Rainfed green peas should be drilled (25 cm × 10 cm spacing) in the last week of September to first week of October after maize harvesting when monsoon rains recede.

After harvesting of all the green pods, all the above-ground biomass of crop (~500–1,000 kg/ha) should be mixed into the soil. Rainfed wheat varieties like 'VL wheat 892' or 'VL wheat 907' or 'VL wheat 953' can be sown across the slope just after harvesting of pea crop during mid-December. This wheat crop would be harvested in the end of April.

Impacts of the technology

By using AD-AGT, wheat equivalent yields increased by 7.8 t/ha than without AD-AGT. In treated AD-AGT CT fields, rain water conservation was achieved at a rate of 1,100–1,300 mm/ha/yr, soil erosion by runoff water was declined by 80–90% compared to CT fields. In addition to this, 11.7 tonnes soil was also conserved annually from a hectare field besides extra build-up of 5.13 t/ha soil organic carbon.

SUMMARY

The study generated scientific evidence supporting the feasibility of triple cropping in a maize–green pea–wheat rotation under a purely rainfed system in the north-western Himalayan region, provided farmers apply AD-AGTs at proper rates and with appropriate configuration. In this study, an additional catch crop of vegetable pea in autumn season was introduced in between rainfed rainy season maize and winter wheat crops for the sustainable crop intensification. This practice enhanced cropping intensity of pure rainfed slopping lands from present 200% to 300% and wheat equivalent yields increased from 6.3 to 14.1 t/ha. In treated AD-AGT CT fields, rain water conservation was achieved at a rate of 1,100–1,300 mm/ha/yr. In addition to this, 11.7 tonnes soil was also conserved annually from a hectare field. Gross return of growing three crops in a year was ₹262,081/ha. Share of the direct and in-direct benefits of the technology were 63 and 37%, respectively. For sustainable practice, the study recommends valourising *Arundo donax* biomass, which currently has no commercial value for farmers. Its effects may vary depending on slope class, rainfall intensity, soil type, and farm size. Thus, incorporation of *Arundo donax* as an agro-geotextile option is good for soil conservation in the slopes.

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