

**Appraisal of agroforestry land use systems on
farmers' own lands for their carbon sequestration
potential in mid himalayan region of
Himachal Pradesh, india**

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Introduction

- Short Rotation Forest trees in Mountain agricultural landscapes are major potential sinks and absorb large quantities of carbon if judiciously managed together with crops and/or animals.
- By promoting agroforestry systems with higher carbon contents than the existing plant community, net gains in carbon stocks can be realised.
- The most significant increase in carbon storage can be achieved by moving from lower biomass landuse systems to agroforestry systems.
- The potential of agroforestry has not been adequately exploited as an effective carbon sink.

- Carbon sequestered through agroforestry plantations on farmers' own lands is one of the non-monetary output and can earn financial returns to the farmers in the form of carbon credits under CDM.
- Carbon sequestered by agroforestry land use in its multiple plant species and soil is a function of structural composition of the system and management practices imposed by the farmers to harvest the needed output.
- The current study is an attempt to assess the structural composition and biomass dynamics as total biomass produced, labile biomass which is harvested to fulfill the farmers' needs and net biomass retained in the system, annually.

Expanding Agriculture – Forest Interface – SRF a solution in Indian Himalayas ?



OBJECTIVES

- 1. Determine net biomass carbon uptake and emissions from agroforestry land use systems managed by the farmers.**
- 2. Establish climate change mitigation and carbon credit production potential of different land use systems in vogue on farmers' private lands.**
- 3. Develop green house gas - carbon inventory for the area of study.**

Locality factors of the Kwalkhad watershed the study site in mid himlayan region of H.P India

Area	1646.00 ha
Latitude	30°45'00" to 30°54'45" N
Longitude	77°03'15" to 77°13'35" E
Altitude	900 to 2100 m asl
Climate type	Sub-humid sub-tropical
MAT	19.80°C
MAP	1150 mm
Soil type	Alfisols, mollisols, inceptisols and entisols
Texture	loam
Parent material	Ferromagnesium shales and dolomitic limestones
Soil pH	5. to 7.2

Structural components and biomass assessment approach

A. Structural Components

- i) Annual crops: Cereals, pulses, vegetables
- ii) Perennials/ woody species
 - Fodder tree species
 - Timber tree species
 - Fruit tree species
- iii) Grasses

A	B	C
<p>Total biomass accumulated (tonnes ha⁻¹) OR = total carbon uptake/ removal</p> <p>Biomass of perennials + annuals during the year of measurement.</p>	<p>Removed/ harvested biomass due to farming practices followed (tonnes ha⁻¹) OR = Carbon emitted</p> <p>Above ground from annuals + foliage + branch wood for fuel + Fruits, etc.</p>	<p>Retained biomass (tonnes ha⁻¹) OR = Carbon mitigated</p> <p>(A-B)</p>

Agroforestry in a small village of Kwalkhad watershed, mid hills of Himachal Pradesh, India



**Prevalence and land area occupied by different landuse systems in
Kwalkhad watershed located in mid Himalayan region of H.P. India**

Land use system	Systems Units (Nos.)	Land area (ha)	
		Range	Mean
Agri-silvi-horticulture (ASH)	23	0.08-2.00	0.69
Agri-horti-silviculture (AHS)	12	0.12-1.60	0.79
Agri-silviculture (AS)	05	0.36-0.72	0.49
Agri-horticultutre (AH)	05	0.04-0.80	0.33
Silvi-pasture (SP)	16	0.08-5.60	1.74
Pure agriculture (PA)	04	0.19-0.77	0.46
Pure grassland (PG)	11	0.08-1.60	0.45
Abandoned land (AL)	03	2.40-1.04	1.45

Farmers' preference for Agroforestry systems

***On the basis of number of system units of a particular system present agri-silvi-horticulture followed by silvi-pasture were the most preferred whereas pure agriculture and abandoned lands were least in practice.**

**ASH (23) > SP (16) > AHS (12) > PG (11)
> AH = AS > PA> AL**

***On the basis of average land area (ha) occupied per system unit silvi-pasture system had the highest land area occupied whereas the agri-horticulture the minimum.**

**SP (1.74) > AL (1.45) > AHS (0.79) > ASH (0.69)
> AS (0.49) > PA (0.46) > PG (0.45) > AH (0.33)**

Preferred tree species and their density (per ha.) in different Agroforestry Systems of Kwalkhad watershed of H.P. India

S. No	Agroforestry System	Forestry spp. (Nos.)	Total No.	Fruit spp.(Nos.)	Total No.	G. Total
1.	Agri-silvi-horticulture	Acacia catechu (3), Dalbergia sissoo(3), Celtis australis(19), Ficus spp.(9), Grewia optiva(17), Q. leucotrichophora(4), Toona ciliata (9)	64	Prunus armeniaca (10), Punica granatum(22)	32	96
2.	Agri-horti-silviculture	A. chinensis(1), C. australis (16), G. Optiva (9), T. Ciliata (6)	32	P. armeniaca(4), Citrus spp.(5), Pyrus communis (25), Purnus siliciana (6), Punica granatum(38)	78	110

**Preferred tree species and their density (per ha.) in
different Agroforestry Systems of Kwalkhad watershed of
H.P. India contd.....**

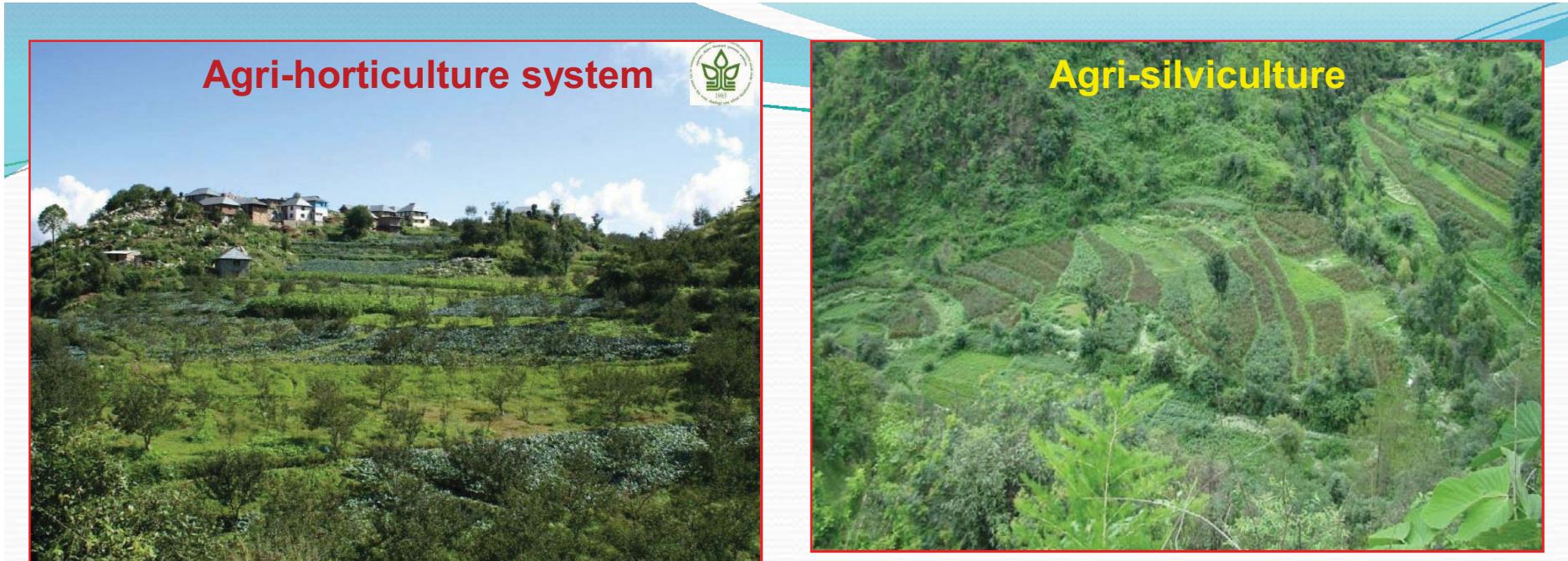
S. No	Agroforestry System	Forestry spp. (Nos.)	Total No.	Fruit spp.(Nos.)	Total No.	G. Total
3.	Agri-silviculture	<i>C. australis</i> (8), <i>Ficus</i> spp.(9), <i>G. optiva</i> (13), <i>Melia azedarach</i> (2), <i>Pyrus</i> <i>pashia</i> (2), <i>T. ciliata</i> (2), <i>Ulmus villosa</i> (2)	38	-	-	38
4.	Agri-horticulture	-	-	<i>Embla</i> <i>officinalis</i> (24), <i>Citrus</i> spp.(24), <i>P.</i> <i>armeniaca</i> (15), <i>P.</i> <i>saliciana</i> (3), <i>Pinica</i> <i>granatum</i> (3)	69	69
5.	Silvi-pasture	<i>A. catechu</i> (29), <i>C.</i> <i>australis</i> (1), <i>Pinus</i> <i>roxburghii</i> (49), <i>Pyrus</i> <i>pashia</i> (3), <i>Q.</i> <i>leucotrichophora</i> (8),	90	-	-	90

**Mean accumulated, removed and retained
biomass (tonnes ha⁻¹) by different land use systems
in Kwalkhad watershed of H.P, India.**

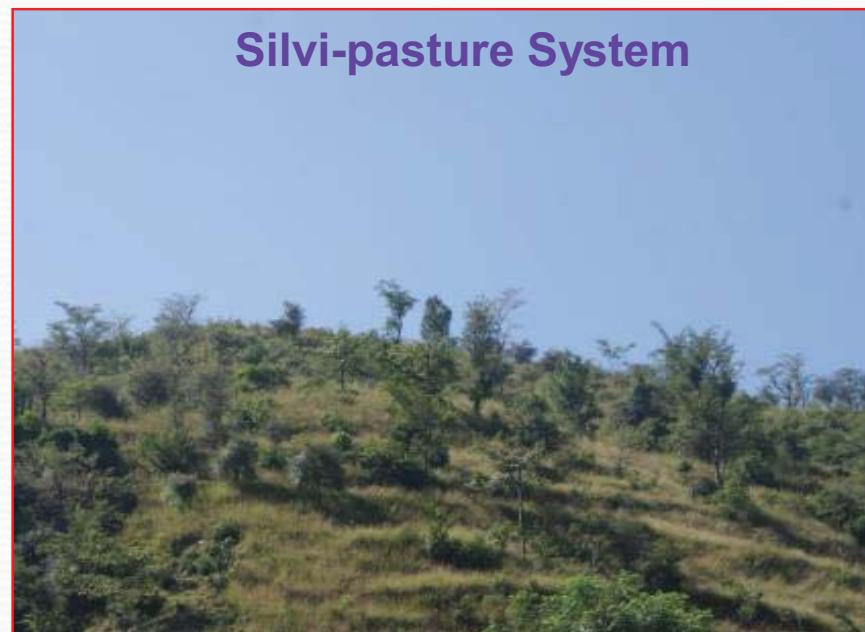
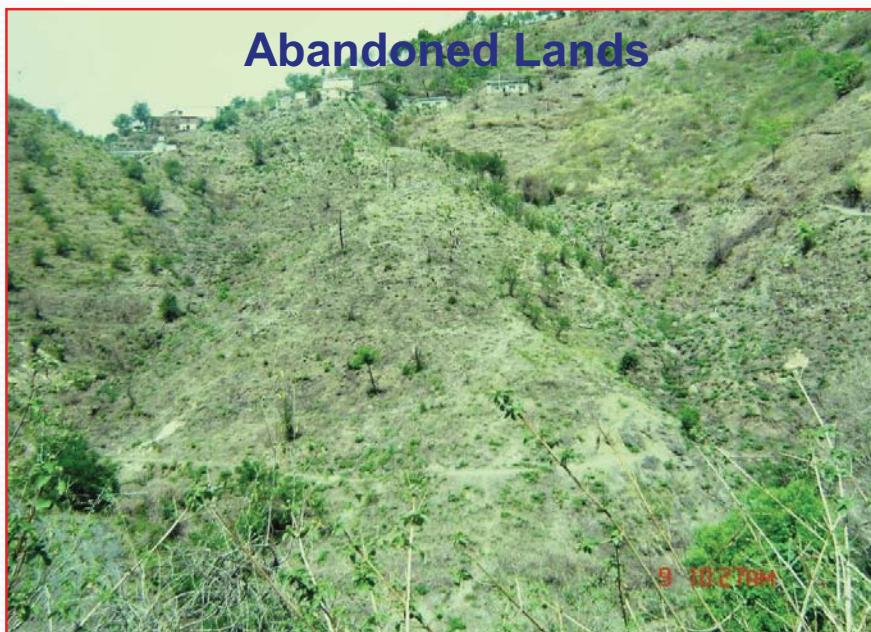
Land use system	Accumulated	Removed	Retained
Agri-silvi-horticulture (ASH)	32.85	19.82	13.03
Agri-horti-silviculture (AHS)	32.01	20.29	11.81
Agri-silviculture (AS)	23.65	15.19	8.46
Agri-horticulture (AH)	26.99	20.32	6.67
Silvi-pasture (SP)	7.48	4.17	3.31
Pure agriculture (PA)	18.31	13.58	4.74
Pure grassland (PG)	2.74	2.26	0.48
Abandoned land (AL)	3.57	0.00	3.57
F value	27.94	23.50	17.05

Biomass accumulation removal and retention pattern of agroforestry systems revealed the following :-

- **Agri-silvi-horticulture and agri-horti-silviculture system accumulated the maximum biomass but these systems were also contributing towards maximum removal of the biomass to meet the different needs of farmers.**
- **The above two systems were followed by agri-silviculture and agri-horticulture system.**

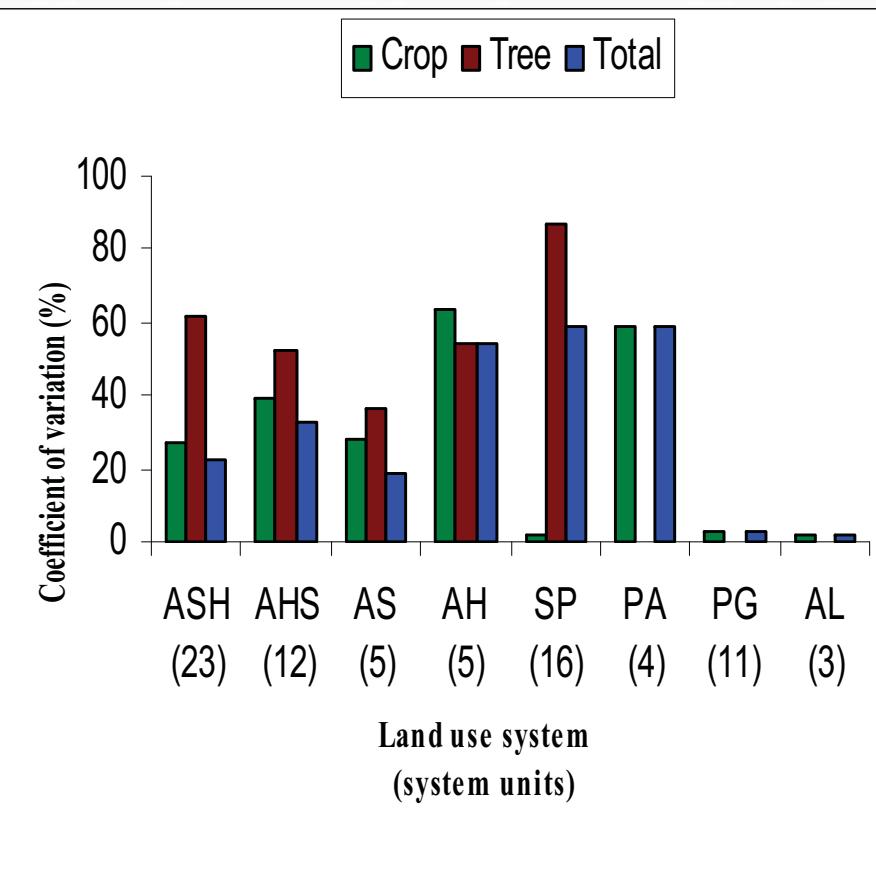


Different forms of natural Agroforestry Systems

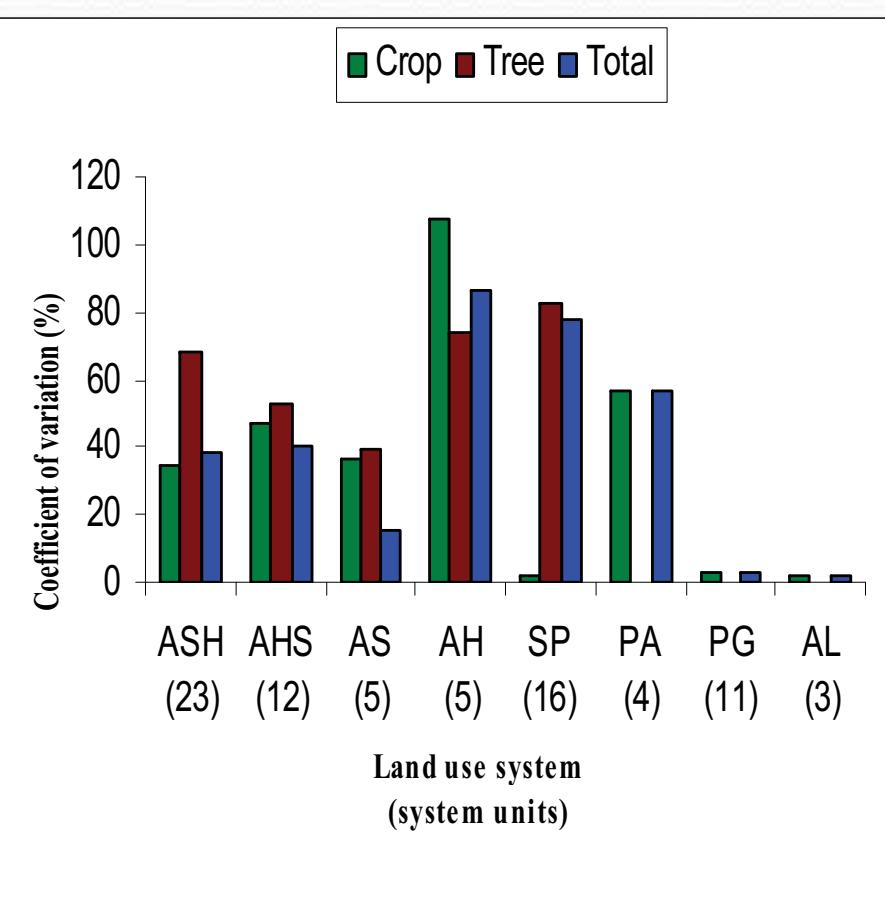


Variability in crop, tree and their total biomass levels of different land use systems

Accumulated biomass



Retained biomass



Current biomass carbon ($Mg\ ha^{-1}$) sequestration, emission and mitigation by different land use systems in Kwalkhad watershed of H.P, India.

Land use systems	Carbon ($Mg\ ha^{-1}$)		
	Sequestered	Emitted	Mitigated
Agri-silvi-horticulture (ASH)	14.78	8.92	5.86
Agri-horti-silviculture (AHS)	14.45	9.13	5.32
Agri-silviculture (AS)	10.64	6.84	3.81
Agri-horticulture (AH)	12.15	9.14	3.01
Silvi-pasture (SP)	3.36	1.88	1.49
Pure agriculture (PA)	8.24	6.11	2.13
Pure grassland (PG)	1.23	1.02	0.21
Abandoned land (AL)	1.60	0.00	1.60
F value	27.94	23.50	17.05

On the basis of mean sequestered, emitted and mitigated carbon ($Mg\ ha^{-1}$) different landuse systems were placed in the following order :-

- **Sequestered carbon:**
ASH>AHS>AH>AS>PA>SP>AL>PG
- **Emitted carbon:**
AH=AHS>ASH>AS>PA>SP>PG>AL
- **Mitigated carbon:**
ASH>AHS>AS>AH>PA>AL>SP>PG

Carbon pool inventory of different land use systems upto 0-20 cm or 0-40 cm soil layers in Kwalkhad watershed of H.P, India.

Land use system	Carbon ($Mg\ ha^{-1}$)					
	0-20 cm			0-40 cm		
	Plant	Soil	Total	Plant	Soil	Total
Agri-silvi-horticulture (ASH)	5.86	52.14	58.00	5.86	95.46	101.32
Agri-horti-silviculture (AHS)	5.32	46.56	51.88	5.32	84.14	89.46
Agri-silviculture (AS)	3.81	50.58	54.29	3.81	92.65	96.36
Agri-horticulture (AH)	3.01	47.73	50.74	3.01	90.07	93.08
Silvi-pasture (SP)	1.49	63.54	65.03	1.49	115.45	116.94
Pure agriculture (PA)	2.13	35.93	38.06	2.13	65.43	67.56
Pure grassland (PG)	0.21	51.67	51.88	0.21	80.15	80.36
Abandoned land (AL)	1.60	86.73	88.33	1.60	164.41	166.01

Highest carbon pool was in abandoned land followed by silvi-pasture, agri-silvi-horticulture and agri-silviculture lad use systems.

Relative carbon mitigation potential of different landuse systems with respect to Pure agriculture in Kwalkhad watershed of H.P, India.

Land use system	Carbon Mitigation Potential	
	Upto 20 cm soil layer	Upto 40 cm soil layer
Agri-silvi-horticulture (ASH)	1.52 (+ 0.52)	1.50 (+ 0.50)
Agri-horti-silviculture (AHS)	1.36 (+ 0.36)	1.32 (+ 0.32)
Agri-silviculture (AS)	1.43 (+ 0.43)	1.43 (+ 0.43)
Agri-horticulture (AH)	1.33 (+ 0.33)	1. 38 (+ 0.38)
Silvi-pasture (SP)	1.71 (+0.71)	1.73 (+ 0.73)
Pure agriculture (PA)	1.00 (\pm 0.00)	1.00 (\pm 0.00)
Pure grassland (PG)	1.36 (+0.36)	1.19 (+ 0.19)
Abandoned land (AL)	2.32 (+ 1.32)	2.46 (+ 1.46)

Carbon credit production potential of different agroforestry systems in Kwalkhad watershed, of H.P India.

Land use system	Estimated total area (ha)	Mitigated carbon (Mg)	Carbon credits*		Value of carbon credits** €***
			Total	Ha ⁻¹	
Agri-silvi-horticulture (ASH)	102.04	598.00	2192	21.49	6576
Agri-horti-silviculture (AHS)	61.11	325.10	1192	19.50	3576
Agri-silviculture (AS)	16.22	60.18	221	13.62	663
Agri-horticulture (AH)	10.66	32.09	118	11.07	354
Silvi-pasture (SP)	178.72	266.30	976	5.46	2928
Total	368.75	1281.67	4699		14097

* 1 carbon credit = 1 ton CO₂ ; ** 1 carbon credit = € 3.00, €***=INR 64

Carbon Mitigation and Carbon credits

- Carbon mitigation potential of abandoned land use was highest (2.46) followed by SP, ASH & AHS with respect to pure agriculture taken as 1 (one).
- Agri-silvi-horticulture (21.49 and Agri-horti-silviculture (19.50) systems yielded maximum number of carbon credits per ha of land area.
- Silvi-pasture system produced the least (5.46) number of carbon credits per ha under current management due to less tree density which was 90 trees ha^{-1} .
- World Bank on May 22, 2011 signed an agreement with Government of Himachal Pradesh (H.P.) for World's largest and India's first CDM Project covering an area of 4003.07 ha.
- The carbon revenues have been calculated at US\$ 5 per carbon credit.

Thank You

