A DESCRIPTION OF THE CITANDUY WATERSHED, WEST JAVA AND PRELIMINARY ANALYSIS OF CARBON-SEQUESTRATION POTENTIAL BY SMALLHOLDERS[1]

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1. Introduction

The Citanduy watershed is situated in the southeast of West Java and is one of 22 critical watersheds in Indonesia. Because of its critical status, the watershed has been prioritised for land rehabilitation and soil conservation. This paper presents background information on the Citanduy watershed, with particular emphasis on the biophysical environment and socio-economic characteristics. The paper provides information to design a study on the carbon sequestration potential of the watershed through land-use change and forestry (LUCF) projects. This describes the biophysical environment of the watershed, including its climate, geology, soils, hydrology, and vegetation; it then provides a profile of the social and economic structure of the area, including population, occupational structure and educational level. The paper then describes land uses and the distribution of land and forest resources in the watershed, including the extent of forest and types of species commonly found in the study area. A brief review of government interventions is presented, followed by a preliminary analysis of carbon sequestration potential in smallholder systems in the area. The paper concludes with a brief section on research needs.

2. The concept of a watershed system

A watershed or water catchment area is defined as a terrestrial entity confined by hills or mountain sides that capture rainfall and direct the flow of water through small rivers into a larger, main river which flows into the sea or a lake. A watershed can be viewed as an ecosystem of its own. A watershed generally has one or more sub-watersheds of smaller rivers. In relation to a hydrological system, a watershed has specific land-use characteristics related to its main elements such as soil type, land-use and topography. Among these elements slope can be modified by humans to influence the hydrological system (Asdak, 1995). Socio-economic factors such as population density and growth and prosperity level also play an important role in watershed performance. Agricultural and forestry practices can greatly affect the watershed. An understanding of the relationships among these factors, along with government intervention (through development programs) and public participation can lead to desirable outputs (Figure 1).

Vegetation cover is an important factor influencing watershed performance. Forests and agroforests, for example, are known to positively affect hydrology and prevent soil loss in a watershed system.

Forests in watersheds provide the following functions (Susswein *et al*., 2001):

- Maintenance of high-quality water
- Regulation of water quantity
- Maintaining water-sediment balance in watershed

[1] Working paper CC09 (2003), ACIAR project ASEM 1999/093, http://www.une.edu.au/febl/Econ/carbon/.

The effectiveness of forests to impact upon these functions, however, depends on the amount and type of forest and the various land-use practices that may follow forest conversion. Agroforestry mosaics may be as effective at protecting watershed functions as the original forest cover (van Noordwijk, 2000 cited in Susswein *et al*. 2001).

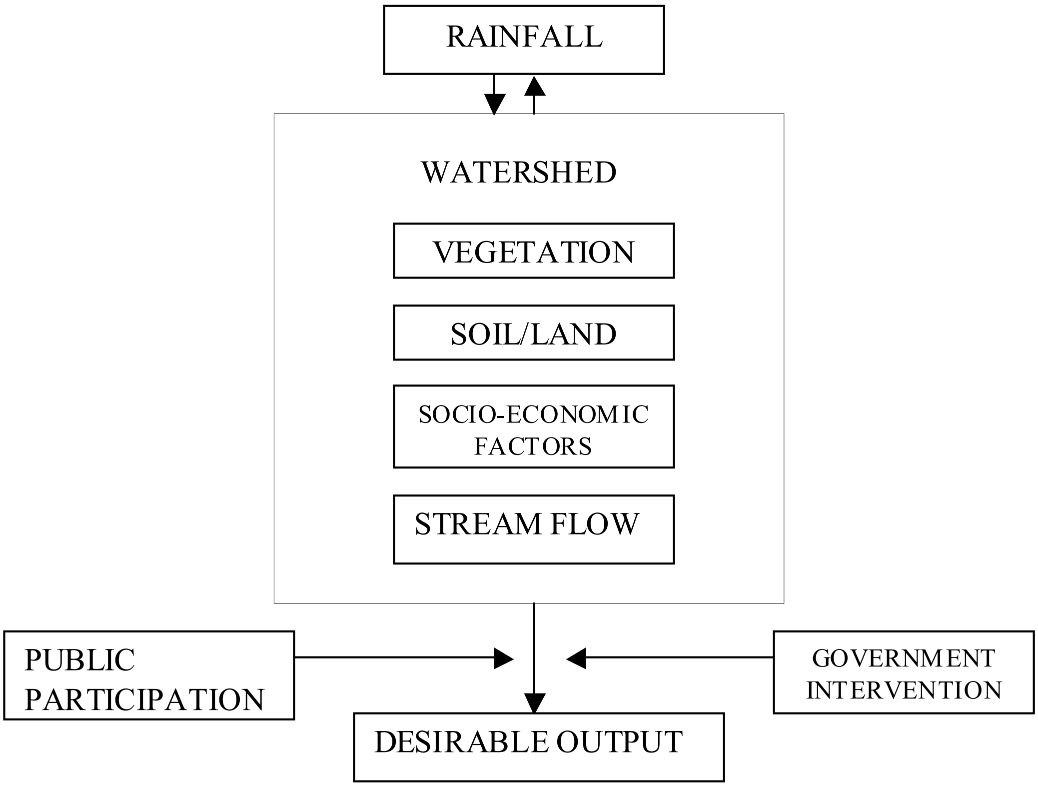

Figure 1. Elements of a watershed and desirable outputs

3. General characteristics of the Citanduy Watershed

The Citanduy watershed is one of 22 critical watersheds in terms of hydrology and erosion in Indonesia. Due to its critical status, the watershed has been prioritised for land rehabilitation and conservation. The Citanduy watershed lies within the south-east of West Java and a small part of Central Java (Figure 2). The Citanduy river is the main river in the watershed. It flows to Indian (often called locally as Indonesia) ocean and forms an estuary called “Segara anakan” located on the border between the West and Central Java provinces (Figure 2). The total watershed area is 352 080 hectares. It comprises five sub-watersheds: Citanduy Hulu (Upper Citanduy), Cijolang, Cimuntur, Ciseel, and Cikawung. The largest is the Upper Citanduy sub-watershed with an area of 95 500 ha or 27% of the watershed. Geographically the Upper Citanduy lies between 7°02’30” – 7°25’30” South and 107°14’.00” – 107°41’30” East, while the Cijolang sub-watershed on the other end of the river lies between 7°0’43” – 7°22’30” South and 108°15’28”-108°38’43” East. The area of each sub-watershed is presented in Table 1.

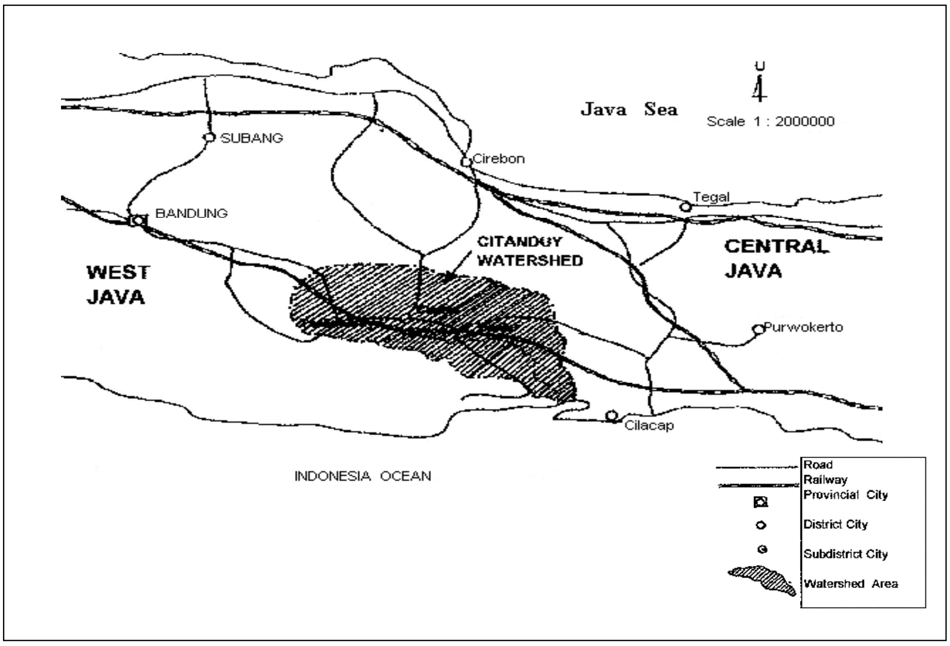

Figure 2. Location of the Citanduy Watershed

The watershed covers part or most of seven administrative districts (kabupaten). They include the Tasikmalaya, Ciamis, Majalengka, Kuningan, and Garut districts of West Java, and part of the Cilacap district in Central Java. The Ciamis district has the largest proportion covered by the Citanduy watershed. The three districts with the most coverage of the watershed are presented in Table 2. These districts contain 89.4% of the Citanduy watershed while the remaining districts cover only 10.6% of the watershed. Regarding hydrological importance, the Ciamis and Tasikmalaya districts cover 35.5% and 59.5% of the Upper Citanduy sub-watershed, respectively. In terms of strategic importance, Ciamis is the most important district in the Citanduy watershed, followed by Tasikmalaya district. These districts generally have light to moderate terrain. The altitude of the Tasikmalaya district ranges between 25 and 800 meters above sea level (m.a.s.l).

Table 1. The extent of each of the sub-watersheds in the Citanduy watershed

No.	Sub-watershed	Area (ha)	% of total
1	Upper Citanduy	74 800	21.3
2	Cimuntur	60 500	17.2
3	Cijolang	48 030	13.6
4	Ciseel	96 500	27.4
5	Cikawung	72 250	20.5
	Total Citanduy watershed	352 080	100

Source: BRLKT (Institute for Land Rehabilitation and Soil Conservation) for Citanduy and Cisanggarung (1999)

Table 2. The extent of districts in Citanduy watershed

No.	District	Total area (ha)	Overlapping area with watershed
1	Ciamis	255 911	186 115 ha (72.7%)
2	Tasikmalaya	284 647	63 761 ha (22.4%)
3	Cilacap	213 850	65 036 ha (30.4%)

Source: BRLKT (Institute for Land Rehabilitation and Soil Conservation) for Citanduy and Cisanggarung (1999)

4. Land and soil characteristics of the Citanduy watershed

4.1 Land characteristics

'Land capability' characterizes the capability of land for particular purposes such as farming or agriculture. Factors that affect land capability are mainly biophysical, such as altitude, slope, drainage, texture, erosion, and soil depth. The land characteristics of the sub-watersheds are presented in Table 3. The Upper Citanduy is the highest with an altitude of 1058 m.a.s.l, while Cijolang in the lower part of the Citanduy river, ranges from 286 to 598 m.a.s.l. Almost 40% of the watershed has slopes greater than 25%.

Table 3. Land characteristics of sub-watersheds in the Citanduy watershed

No.	Sub-watershed	Land parameter & characteristics	Area (ha)	% of area
1	Upper Citanduy	Altitude (metre)		
		1058		
		Slope (%)		
		0 – 8	5 377	7
		8-15	23 521	31
		15-25	15 392	21
		25-45	22 693	30
		> 45	7 815	11
2	Cijolang	Altitude (metre)		
		286 – 598		
		Slope (%)		
		0 – 8	5 456	11
		8-15	8 240	17
		15-25	14 187	30
		25-45	14 772	31
		> 45	5 373	11
3	Ciseel	Altitude (metre)		
		176		
		Slope (%)		
		0 – 8	35 255	37
		8-15	5 326	6
		15-25	20 348	21
		25-45	25 847	27
		> 45	9 723	10
4	Cimuntur	Altitude (metre)		
		518		
		Slope (%)		
		0 – 8	6 424	11
		8-15	23 282	38
		15-25	12 856	21
		25-45	12 583	21
		> 45	5 355	9
5	Cikawung	Altitude (metre)		
		548		
		Slope (%)		
		0 – 8	20 262	28
		8-15	7 739	11
		15-25	8 046	11
		25-45	28 443	39
		> 45	7 759	11

Source : Institute for land rehabilitation and conservation for Citanduy-Cisanggarung (1989)

Soil erosion potential varies between, and within, sub-watersheds. Soil erosion potential is the predicted maximum soil loss on a piece of land in the long run, assuming vegetation and soil conservation are maintained at current levels, taking into account solumn depth[2]. The Cikawung sub-watershed has the highest soil erosion potential in terms of area with high to very-high erosion potential, constituting 21.6% of the area. However, if moderate erosion level is included, the Cimuntur sub-watershed has the largest percentage (59%) of the total area.

Table 4. Soil erosion potential in the Citanduy watershed

No.	Erosion potential	Area (ha)	% of area
1	Very low	135 263	38.4
2	Low	92 130	26.2
3	Moderate	89 264	25.3
4	High	28 856	8.2
5	Very high	6 566	1.9

Source: Institute for Land Rehabilitation and Soil Conservation for Citanduy and Cisanggarung, 1999 (data processed).

4.2 Soil types

In general, there is no dominant soil type in the Citanduy watershed and there is variation in soil type from one sub-watershed to another. The major soil type found in the watershed is red and red-yellow latosol (21.36%). Table 5 lists each soil type and the area covered by each soil type.

Table 5. The Citanduy sub-watersheds and soil types

No.	Sub-watershed	Soil type	Area (ha)	Area (%)
1	Upper Citanduy	1. Kambisol, Gleisol	28 153	38
		2. Latosol	44 924	60
		3. Mediteran	-	-
		4. Red-yellow podzolic	1 723	2
2	Cijolang	1. Alluvial	41 248	85.9
		2. Latosol, organosol	2 133	4.5
		3. Mediteran	4 649	9.7
3	Ciseel	1. Kambisol, gleisol,planosol, alluvial	42 120	43.6
		2. Latosol	11 952	12.4
		3. Mediteran	6 162	6.4
		4. Red yellow podzolic	35 612	36.9
		5. Litosol,renzina,regosol,organosol	654	0.7
4	Cimuntur	1.Gleisol	5 516	9.1
		2.Kambisol	1 178	1.9
		3.Latosol	53 806	89
5	Cikawung	1.Alluvial	18 427	25.5
		2.Latosol	29 452	40.8
		3.Mediteran	3 149	4.3
		4.Andosol	21 222	29.4

Source: Institute for Land Rehabilitation and Soil Conservation for Citanduy and Cisanggarung, 1999.

[2] Note: Another erosion potential classification is based on the USFL method, where Class I: < 15, II: 15 ≤ 60, III: 60 ≤ 180, IV: 180 ≤ 480, and V: > 480 ton/ha/yr. In this classification, however, solumn depth is not taken into account.

4.3 Climate

Climate type varies from one sub-watershed to another. According to Schmidt and Ferguson (1951), the climate type of the Upper Citanduy sub-watershed is of type A, or if the Koppen (1918) classification scheme is used it is type A_{fa}. Using the Schmidt and Ferguson classification, Ciseel is of type B while Cijolang, Cikawung and Cimuntur all belong to type C.

Based on agro-climatic zone classification (Oldeman,1979), Upper Citanduy belongs to zone B_2, Cijolang belongs to zone I_a, Ciseel to zone C_2, and Cimuntur to B_1. Details of the climate of each sub-watershed are presented in Table 6.

Table 6. The climate in the Citanduy watershed

No.	Sub-watershed	Ave.Rainfall (mm/y)	No. of Wet months/y *	Humidity (%)	Temperature (°C)
1	Upper Citanduy	3066	7-9	79-82	21-26
2	Cijolang	1804	8	88-92	27-30
3	Ciseel	2958	6-7	n.a.	26-30
4	Cimuntur	2500-3000	8	83-84	21-34
5	Cikawung	2758	6-7	84	22-25

Source : Institute for Land Rehabilitation and conservation for Citanduy and Cisanggarung (1995, 2000).
* A 'wet month' is a month with rainfall > 200mm.

4.4 Hydrology

Watershed hydrology is affected by rainfall, stream flow, infiltration, evaporation, and other elements that affect water balance. Parameters of particular interest in watershed hydrology are water run-off, erosion (or siltation) and fluctuations in stream-flows through time. These parameters are used as indicators of the health of watershed. One frequently used indicator to characterize watershed performance is the proportion of maximum to minimum stream flows (Qmax/Qmin) in the river – the values for each sub-watershed are presented Table 7. A tolerable Qmax/Qmin is considered to be 40 (or 40:1) and a tolerable erosion rate is considered to be 15 tons/ha/yr. The Qmax/Qmin and erosion values for most of the sub-watersheds in the Citanduy watershed are far above the tolerable limit. The fluctuation of maximum and minimum stream flows become extreme between the Upper Citanduy and Cijolang (downstream) sub-watersheds, as do the rates of erosion.

Table 7. Stream flow fluctuations in the Citanduy watershed as indicated by the parameter Qmax/Qmin

No.	Sub-watershed	Qmax/Qmin	Erosion rate (ton/ha/yr)
1	Upper Citanduy	14	24.0
2	Cijolang	5451	110.4
3	Ciseel	242	55.1
4	Cimuntur	268	40.5
5	Cikawung	382	38.4

Source: Institute for Land Rehabilitation and Conservation for Citanduy and Cisanggarung (1997, 2000)

4.5 Vegetation

Vegetation cover in the watershed generally consists of perennial crops, horticultural crops, and trees. Vegetation in state-protected forests is dominated by tree species such as rasamala (*Altingia excelsa*), puspa (*Schima noronhae*), and mahoni (*Swietenia macrophylla*). While in state-production forests, dominant species are jati (*Tectona grandis*) and pinus (*Pinus merkusii*). Agroforests belonging to small-holders are also present, and these are characterised with three main species namely, sengon (*Paraserianthes falcataria*), mahoni (*Swietenia macrophylla*), and teak (*Tectona grandis*). These are usually mixed with perennial and horticultural crops.

Outside forests and agroforests, agricultural land is planted with horticultural plants such as rice paddy, vegetables, cassava, beans and perennial crops such as coconut, clove, rubber, and fruits. Paddy fields cover a significant part of agricultural lands since rice is the staple food.

4.6 General land classification

General land classification is determined by the Indonesia Ministry of Agriculture (through Minister's decrees No. 837 of 1980 and No. 683 of 1981), namely:

1. Protection area
2. Buffer area
3. Agriculture area
4. Settlement area

Factors determining the classification are: (i) Land slope (in percent), (ii) Soil type according to sensitivity to erosion, and (iii) Average daily rainfall. Data and information regarding these factors are interpreted from topographic and soil maps and from rainfall data collected from field stations. Scoring is applied to each factor: the 'land slope' factor ranges from 20 to 100; 'sensitivity to erosion' ranges from 15 to 75, and 'daily rainfall intensity' ranges from 20 to 50.

Based on the total score, land suitability is determined as:

a. 'Protection area' if total score > 175

b. 'Buffer area' if total score is between 124 – 174

c. 'Agriculture area with perennial plants' if total score < 124 and the land is suitable for perennial plants,

d. 'Agriculture area with horticulture plants' if total score < 124 and the land is suitable for horticultural plants.

e. 'Settlement area': agriculture area suitable for settlement with land slope between 0 – 8%.

5. Socio-economic aspects

5.1. Land-use and forest resources

Land-uses in the Citanduy watershed in 1998 are detailed in Table 8. The largest proportion (54.6%) of the watershed is farms that belong to small-holders such as fruit gardens, perennial crop-lands, and agroforests. Paddy fields occupy the second largest area (20.5%) while state forests make up 14.6% of the total area.

Table 8. Land uses in the Citanduy watershed

No	Sub-watershed	Land use	Extent (ha)	%
1	Upper Citanduy	a. State forest	13 639.29	3.87
		b. Estate crops	-	-
		c. Small holder farm	32 879.24	9.34
		d. Paddy field	19 534.29	5.55
		e. Settlement area	8 600.46	2.44
		f. Mining	-	-
		g. Others	146.72	0.04
	Sub total		74 800	21.24
2	Ciseel	a. State forest	4 325.91	1.23
		b. Estate crops	1 339.57	0.38
		c. Small holder farm	64 752.75	18.39
		d. Paddy field	19 744.97	5.61
		e. Settlement area	5 083.95	1.44
		f. Mining	369.20	0.10
		g. Others	883.65	0.25
	Sub total		96 600	27.44
3	Cimuntur	a. State forest	5 135.44	1.46
		b. Estate crops	1 995.03	0.56
		c. Small holder farm	39 494.64	11.22
		d. Paddy field	10 938.27	3.10
		e. Settlement area	2 365.02	0.67
		f. Mining	-	-
		g. Others	571.60	0.16
	Sub total		60 500.00	17.18
4	Cijolang	a. State forest	12 293.72	3.49
		b. Estate crops	2 652.47	0.75
		c. Small holder farm	20 952.46	5.95
		d. Paddy field	9 500.51	2.70
		e. Settlement area	583.09	0.16
		f. Mining	-	-
		g. Others	2 047.75	0.58
	Sub total		48 030.00	13.64
5	Cikawung	a. State forest	16 016.56	4.55
		b. Estate crops	6 098.83	1.73
		c. Small holder farm	33 165.39	9.42
		d. Paddy field	12 624.30	3.58
		e. Settlement area	4 344.91	1.23
		f. Mining	-	-
		g. Others	-	-
	Sub total		72 250.00	20.52
	TOTAL		352 080.00	100.00

Agricultural products and estate crops are important products in the local economy not only in the Citanduy watershed but also for the Ciamis and Tasikmalaya districts. Rice production alone contributes around 40% of Gross Domestic Product. Timber is also an important product to the local economy and is produced by State Forestry Enterprise PT Perhutani from its production forests, and by private agroforests. PT Perhutani conducts regular annual cutting to produce teak, mahoni, and pine round-wood while the private land produces sengon, mahoni, and a few other species. Timber is in high demand for home-building and larger wood-based industries in Tasikmalaya, Ciamis, and other local and international markets. The pressure on forests is quite high as the demand for round-wood far exceeds supply. This problem is not unique and is widespread throughout the country.

Although there is variation in land uses from one sub-watershed to another, rice fields, farm lands, and forest are important in all sub-watersheds. Rice fields and small-holders' farms constitute the largest portion of land use in every sub-watershed. State forests account for 14.6% of the total watershed area. However, total forested areas for the watershed exceed this when small-holder agroforests are included. The extent of state-forest land and small-holder agroforests in Ciamis, Tasikmalaya, and Cilacap districts is around 22% of the total area with small-holder forestry/agroforestry systems accounting for 7% of the total.

5.2. Land ownership

Land ownership in Citanduy watershed can be divided into two categories: state land and small holder or private land. State lands can further be divided into state-forest land, state land for commercial use (HGU), and other state lands. HGU is a 30-year right/license to grow commercial estate crops or plantations. The size of smallholdings is usually quite small averaging about 0.4 ha/landowner. Private land ownership in the Upper Citanduy watershed comprises 68.5% where smallholdings are < 0.25 ha, 29.5% where smallholdings are between 0.25 and 1.0 ha, and 4.7% where smallholdings are > 1.0 ha.

5.3. Population

The Citanduy watershed, like elsewhere in West Java, is densely populated. The structure of the population is presented in Table 9. Population density varies greatly from one sub-watershed to another. The Upper Citanduy sub-watershed is the most populous. In total, population density for the Citanduy watershed is approximately 833 people/km^2. The highest population growth occurs in Cikawung and the lowest occurs in Cimuntur.

Table 9. Population by age of the Citanduy watershed in 1996

No.	Sub-watershed	AGE (y)			Total	Growth
		0 - 15	16 - 55	> 56		
1	Upper Citanduy	347 858	599 117	122 332	1 069 307	1.23%
2	Ciseel	304 491	337 913	95 607	637 378	1.75%
3	Cijolang	84 270	132 509	50 844	272 476	0.60%
4	Cikawung	132 811	242 164	51 047	426 022	1.90%
5	Cimuntur	162 628	263 211	95 108	525 947	0.37%
	TOTAL				2 931 130	

Source : Institute for Land Rehabilitation and Conservation for Citanduy and Cisanggarung (1999, 2000)

5.4. Education

The educational level of the population in the Citanduy watershed is mostly of elementary-school standard (52%), followed by junior high-school standard, then senior high-school standard, and finally by university graduate level. University/academy graduates represent only 1% of the population and quite a number of people (12%) have no formal education whatsoever (i.e. they may not have finished their elementary education).

Table 10. Population by education level in the Citanduy watershed, in 1996.

No.	Sub-watershed	Education Level						TOTAL
		SD	SLP	SLA	Academy/ University	No. in education	Others	
1	Upper Citanduy	468 185	133 991	110 308	17 073	131 627	209 879	1 071 063
2	Ciseel	343 648	65 276	42 225	5 542	72 939	67 811	597 441
3	Cijolang	135 397	34 507	19 678	2 185	29 487	53 322	272 467
4	Cikawung	264 114	61 250	22 183	1 297	47 889	15 741	412 474
5	Cimuntur	300 274	71 470	40 082	4 688	52 578	66 855	525 947
	TOTAL	1 511 618	366 494	234 476	30 785	334 520	413 608	2 879 392

Remark : SD = Elementary school, SLP = Junior High school, SLA=Senior High school, Institute for Land Rehabilitation and Conservation for Citanduy and Cisanggarung (1999)

5.5. Employment

The majority of employment in the Citanduy watershed (Table 11) is made up of farmers (58%) followed by labour (15.5%). This shows that agriculture is the most important source of income in the region. The fact that agriculture provides most of the employment in the region means that there is pressure for more land, even conservation areas and forested lands, to be converted to horticulture or to growing other food crops.

Table 11. Employment in the Citanduy watershed

No	Sub-watershed	Livelihood						Total
		Farmer	Trader	State employee	Labour	Hand crafter	Others	
1	Upper Citanduy	286 913	57 844	35 841	139 432	17 573	64 161	601 764
2	Ciseel	212 314	17 664	18 963	22 396	17 673	43 542	332 552
3	Cijolang	103 400	4 402	5 688	6 631	7 413	20 456	147 990
4	Cimuntur	298 191	8 800	18 158	24 379	13 129	41 783	404 440
5	Cikawung	149 717	8 691	7 057	94 766	9 367	7 028	266 626
	Total	1050 544	97 201	65 507	277 604	65 155	176 970	1792 072

Source: Institute for Land Rehabilitation and Soil Conservation for Citanduy and Cisanggarung (1999)

5.6. Gross domestic product (GDP)

The contribution of each sector to GDP is illustrated using the Tasikmalaya district (Table 12). The agricultural sector contributed most to GDP (27.7%), followed by trade (24%). Forestry provided only a relatively small contribution to the agricultural sector (1.54%).

Table 12. The contribution of different sectors of the economy to GDP in the Tasikmalaya district in 1996

No.	Sector	Rp (x 10^6)	%
1	Agriculture, Animal Husbandry, Forestry,and Fishery	**749 079**	27.70
	a. Food crops	513 949	
	b. Estate crops	68 526	
	c. Husbandry	76 661	
	d. Forestry	11 549	
	e. Fishery	78 394	
2	Mining	**4 985**	0.18
3	Processing industries	**220 970**	8.18
4	Electricity, Gas, Water	**10 672**	0.39
5	Construction	**343 804**	12.70
6	Retail, Hotel, Restaurant	**649 199**	24.00
7	Transportation, Communication	**163 017**	6.00
8	Finance, Rental, Commercial Services	**168 264**	6.20
9	Other services	**390 259**	14.45
	TOTAL	**2 700 252**	100

Source: Tasikmalaya in Figures (1998). Exchange rate: 1 US$ = Rp 2000

6. Government intervention and programs

Endeavours to maintain soil fertility and water resources within the framework of ecosystem management of watersheds are the focus of the Land Rehabilitation and Soil Conservation program. The program stemmed from Basic Law No. 4 of 1982 about Basic Principles of Environmental Management, Basic Law No. 5 of 1990 about Natural Resources and Biodiversity and the Ecosystem, and Forestry Basic Law No. 5 of 1967 (The Forestry Basic Law has been revised to Forestry Basic Act No. 41 of 1999). At present 22 watersheds in the country have been declared as having a critical status where priority should be given for land rehabilitation and soil conservation.

The main objectives of Land Rehabilitation and Soil Conservation are as follows:

1. To control the rate of erosion and siltation as well as to suppress maximum stream flows in the event of floods.
2. To manage water resources such that stream-flow fluctuations in rivers can be maintained at optimum levels.
3. To improve soil productivity by development of husbandry, agri-business and agro-industry with the aim of increasing farmer incomes.
4. To increase people participation in the endeavours to conserve forest, land and water through human-resource development and farming with conservation ("usahatani konservasi").

Programs have been developed to achieve these objectives, including: Government funded Reforestation and Greening Aid (INPRES), and various programs funded by international donors such as ADB, USAID, FAO, World Bank, JICA. However, these programs have not achieved the desired outcomes. Some of the constraints are (1) limitations to the ownership of land, (2) inter-sector conflicts over land-use, (3) institutional weakness, and (4) poverty – especially for those living in critical lands. An example of institutional weakness in the INPRES program is a lack of coordination between the central government (Ministry of Forestry) and local governments in program implementation. This might stem from different perceptions and interests between planning and executing agencies. Planning and funding were conducted by the central government while the plan implementation was conducted by local governments (district). The central government perceives the watershed as an entity (or system) in which development should be targeted; however the development that has taken place in districts often negated this orientation. There is also a lack of coordination among districts located in the same watershed such as in Citanduy. In essence, there is no coherent strategy among districts to achieve the "watershed-oriented goal". Decentralization has taken place recently in the country as a consequence of the implementation of Act No 22 of 1999. This act has given more authority to districts to manage their own natural resources. As a consequence, this program needs new arrangements with respect to planning, funding, budgeting and implementation.

An Institute for Land Rehabilitation and Soil Conservation is established for each critical watershed with responsibility for planning, monitoring, evaluating, and carrying out land rehabilitation and soil conservation endeavours, together with the local Forest Service. Some extension officers are attached to BRLKT to inform and monitor farmers, individually or in groups, on land rehabilitation and soil conservation.

Endeavours that have been conducted by the Institute for Land Rehabilitation and Soil Conservation for Citanduy and the local Forest Service include: (1) giving assistance to farmers engaged in agroforestry, (2) distributing seedlings, (3) establishing demonstration plots of natural resource conservation units, and (4) construction of land terracing.

7. Carbon sequestration potential in smallholder agroforests

A field survey was conducted on agroforests in two Subdistricts of Upper Citanduy, Cisayong and Sadananya, in 2002. The farms sampled were relatively small, with areas ranging from 0.38 to 0.60 ha in Cisayong and 0.25 to 1.0 ha in Sadananya. The results showed that a variety of tree species are found in both districts (Table 13). At least three tree species were found in most farms. A total of 30 species were identified. The most common species was *Paraserienthes falcataria* (308 trees) followed by *Maeopsis eminii* (118 trees) and *Swietenia macrophylla* (78 trees).

Sampling consisted on measuring the diameter and height of each tree. The volume, biomass and carbon content per tree and per hectare were calculated. The following formulas were applied:

$$Vol = \frac{\pi \times H \times \left(\frac{D}{2}\right)^2}{3}$$

This is the formula for a cone. *Vol* is the volume of the tree (m^3) *H* is height and *D* is diameter (both expressed in metres).

Table 13. Tree species identified in field survey in Upper Citanduy

Local name	Scientific Name	Number measured
Afrika	*Maeopsis eminii*	118
Alpukat	*Persea americana*	7
Cempedak	*Artocarpus integra*	1
Cengkeh	*Eugenia aromatica*	20
Damar	*Agathis dammara*	2
Durian	*Durio zibethinus*	2
Huru	*Dehasia caesia*	2
Jambu batu	*Psidium guajava*	2
Jengkol	*Pithecellobium jiringa*	4
Johar	*Gliricidia sepium*	3
Kanyere	*Syzigium spp.*	1
Kelapa	*Cocos nucifera*	4
Kemang	*Mangifera spp.*	3
Kiteja	*Cinnamomum spp.*	5
Limus	*Mangifera foetida*	4
Mahoni	*Swietenia macrophylla*	78
Manglid	*Manglidtia glauca*	4
Nangka	*Artocarpus heterophyllus*	16
Petai	*Parkia speciosa*	13
Picung	*Hibiscus sp.*	2
Pinus	*Pinus merkusii*	1
Pisitan	*Lansium sp.*	1
Puspa	*Schima wallichii*	15
Putat	*Planchonia valida*	2
Rambutan	*Nephellium lappaceum*	1
Sengon	*Paraserianthes falcataria*	308
Suren	*Toona surenii*	4
Tangkala	*Litsea spp.*	1
Tangkil	*Gnetum gnemon*	16
Tisuk	*Hibiscus sp.*	16
Total		656

The formula by Ketterings et al. was used to estimate biomass:

$$Biom = 0.11 \times Dens \times (100 \times D)^{2.62}$$

Where *Biom* is biomass (kg) and *Dens* is the density of the wood (t/m^3). The mean annual increments for volume (*MAIV*) and carbon (*MAIC*) were estimated as:

$$MAIV = {Vol}/{Age}$$

$$MAIC = {(0.5 \times Biom)}/{Age}$$

These formulas are expressed on a per-tree basis, the resulting values were then multiplied by the number of trees per hectare and, in the case of *MAIC* divided by 1000 to convert to tonnes. The *MAIC* formula assumes that 50% of biomass is carbon.

Tables 14 and 15 present a preliminary analysis of results to gain an idea of the carbon sequestration potential of smallholder agroforests. A more detailed analysis and description of the sampling strategy will be presented in a forthcoming paper.

Table 14. Summary results for Cisayong sites.

Farm	Mean Age	N	Biomass (tDM/ha)	MAIC (tC/ha/year)	Volume (m^3/ha)	MAIV (m^3/ha/year)
1	2.3	31	18.3	4.2	28.5	14.2
2	2.5	38	50.3	8.3	107.5	36.4
3	2.8	31	81.7	12.1	143.7	48.7
4	4.3	22	61.9	10.5	72.2	28.2
5	4.2	21	35.4	4.7	55.4	15.4
6	3.7	22	28.8	3.7	47.2	13.1
7	4.1	29	56.0	6.6	79.7	20.9
8	2.5	27	32.6	6.1	70.4	26.1
Mean	3.3	27.6	45.6	7.0	75.6	25.4
St. Dev	0.9	5.9	20.7	3.0	36.1	12.3
CV (%)	26.1	21.2	45.4	43.2	47.8	48.7

Table 15. Summary results for Sadananya sites.

Farm	Mean Age	N	Biomass (tDM/ha)	MAIC (tC/ha/year)	Volume (m^3/ha)	MAIV (m^3/ha/year)
1	5.9	25	138.9	11.9	180.8	32.9
2	5.9	72	147.7	9.6	112.7	23.9
3	6.0	43	159.0	11.8	115.0	19.9
4	5.5	37	128.4	11.9	151.8	32.6
5	4.1	26	63.1	6.9	70.1	20.1
6	3.9	27	71.5	7.2	109.0	24.2
7	3.3	41	59.2	8.6	107.9	32.5
8	3.4	37	83.0	11.1	141.6	38.2
9	4.3	27	90.3	8.9	131.8	29.1
10	4.2	28	68.2	6.5	89.0	21.1
11	3.3	45	98.8	13.0	119.3	36.5
12	3.7	36	85.5	11.3	92.7	25.8
Mean	4.5	37.0	99.5	9.9	118.5	28.1
St. Dev.	1.1	13.1	35.0	2.2	29.9	6.4
CV (%)	23.7	35.4	35.2	22.6	25.2	22.9

Aboveground biomass ranged from 18.3 to 61.9 t DM/ha in Cisayong (Table 14) and from 59.2 to 159.0 t DM/ha (Table 15). The means for the two sites were 45.6 and 99.5 t DM/ha. These results are equivalent to carbon stocks of 22.8 and 49.7 t C/ha, and are comparable to the results of Delaney and Roshetko (1999) for home gardens in Indonesia, who measured mean aboveground carbon stocks of 35.3 t C/ha.

Biomass and carbon growth in tree species varied greatly, with average mean annual increment of carbon per tree ranging from 1.8 to 15.5 kg C/tree/y in Cisayong and from 3.1 to 18.6 kg C/tree/y in Sadananya (detailed data not shown).

Mean Annual Increment of Carbon per hectare ranged from 3.7 to 12.1 tC/ha/y in Cisayong and from 6.9 to 13.0 tC/ha/y in Sadananya, with means of 7.0 and 9.9 tC/ha/y for the two sites respectively. The variation among farms is relatively high with coefficients of variation of 43.2% in Cisayong (Table 14) and 22.6 % in Sadananya (Table 15). These values represent only aboveground biomass and do not take account of root carbon, which can be as high as 0.4 times the amount of carbon in aboveground biomass (Hamburg, 2000). Soil carbon was not measured either.

8. Research needs

Intensive research on watershed management has been conducted in the Citanduy watershed. Numerous reports on planning and land rehabilitation activities have been published by various agencies involved in the planning and land rehabilitation of the watershed. However, research on the possible contribution of carbon credits to land rehabilitation is rare, as carbon sequestration is a relatively new issue.

Carbon sequestration can be viewed as an additional benefit that forests and agroforests can generate along with other benefits in the watershed. Therefore, a carbon-credit scheme would be best implemented in synchronization with existing programs.

Research on carbon credits in Citanduy should answer several questions including: (i) What is the contribution of agroforestry and farm-forestry to carbon sequestration in the watershed? (ii) What socio-economic factors drive people to establish agroforests? (iii) What are the establishment costs of agroforests? and (iv) How may agroforest owners benefit from carbon-credit schemes? Answers to these questions may help in formulating policies on the implementation of carbon-credit schemes; particularly in relation to land rehabilitation endeavours. A study addressing these issues will be conducted in the Citanduy watershed. In particular, the study will attempt to find out the carbon sequestration potential of agroforests, and the possible stimulatory effects that carbon sequestration payments might have on agroforestry development.

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