Land Conservation in The Ulu Selo Watershed Through The Concept of Wanatani Agroforestry

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Abstract. The Ulu Selo Sub-Watershed, located in Tanah Datar Regency, West Sumatra, is part of the Indragiri Watershed. The Ulu Selo Sub-Watershed flows from Mount Marapi and empties into the Batang Ombilin River. This river is a stream of water from Lake Singkarak which flows through the hills and meets the Ulu Selo Sub-Watershed to form the Indragiri River. Current farming methods employed by local farmers would not give the best result. Hence, the application of Wanatani was proposed. A survey method was employed to comprehend the notion of Wanatani in this region. Hydrological calculations and plant analyses were also conducted. According to survey and data calculation, this area would experience a water deficit during June, July, August, September, and October, with a total water deficit of 329 mm. Applying the Wanatani system using native plants and animal manure as fertilizer could help the farmers survive during this water deficit season.

Keywords: Agricultural and Agroforestry Climate Zones, Hydrological Analysis, Number of Livestock, Ulu Selo River Sub-Watershed, Wanatani Agroforestry

1 Introduction

The Indragiri watershed originates from the volcanic area, namely from the Sumani sub-watershed, the Ombilin sub-watershed, and the Selo watershed sub-watershed. The Sumani sub-watershed consists of other sub-sub-watersheds, including Imang, Gawan, Aripan, Lembang, and Sumani. Empty in the Lake Singkarak and flowing out through Batang Ombilin River, the Ombilin sub-watershed consists of the Selo sub-watershed, Buak Batang sub-watershed, Katialo sub-watershed, Asam sub-watershed, Malakutan sub-watershed, Parambahan sub-watershed, and Lasi sub-watershed. These sub-watersheds are empty towards Kuantan via the Indragiri River[1], [2]. The upstream part of the Selo watershed originates from Mount Marapi, namely from Tanah Datar Regency, West Sumatra, covering two sub-districts, namely the Sungai Tarab

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sub-district and the Salimpaung sub-district. Sungai Tarab sub-district is upstream of the Selo sub-watershed, which originates from the Batang Bangkahan and the Banda Gadang, emptying into the Batang Selo. The Salimpaung District is home to two rivers: the Batang Aie Banda Gadang River, which spans 6.5 km, and the Batang Selo River, spanning 4 km. The Batang Sumanik originates from Rao-Rao and flows into Sumanik for 3 km; then, all these water bodies empty to form the headwaters of all sub; then, all these water bodies combine to form the headwaters of Selo's sub-watersheds.-watershed of Selo. The area consists of volcanic plains, hilly areas with metamorphic rocks (Hf), hilly areas with granite intrusive rocks (Hg) and limestone sedimentary rocks (Kc), and plain areas with phyllite rocks (Ptps)[3]. This region spans from Mount Marapi in the west to Mount Sago in the east and is characterized by sedimentary rocks consisting of limestone and sandstone. The area falls under agricultural climate zones D1 and D2. According to Odelman, the wet season comprises four non-consecutive months, while the dry season lasts strictly between 3 to 4 months.

Table 1. Physiographic Unit for the Ulu Selo watershed, Tanah Datar Regency, West Sumatra

No		Land Unit Code	Description	Area (ha)			
				Sungai Tarab	Salim-paung	Watershed	%
1	Volcanic plain	Vab.1.2.3	Upper Volcanic Slope	2379.32	638.6	3017.92	14.21
2		Vab 1.2.3	Middle Volcanic Slope	1721.07	301.8	2022.87	9.53
4	Granit intrusion	Hg.1.2.3	Volcanic intrusion	218.88	120	338.88	1.60
5	Volcanic plain	Vab.1.3.3	Middle Volcanic Slope	3225.35	2068.7	5294.05	24.93
6		Vab.1.4.2	Lower Volcanic Slope	4394.1	0	4394.1	20.69
7	Volcanic plain	Vd.2.1.2	Volcanic plain	417.55	1834.4	2251.95	10.61
8	Sediment	Kc 3.3		0	191.5	191.5	0.90
9	Metamorph	Hf.1.2.3		0	3478	3478	16.38
10	phyllite sand rocks	Ptpts		245.19	0	245.19	1.15
	total			12601.46	8633	21234.46	100.00

From the **Table 1**, it can be seen that there are almost no flat areas found in the Ulu Selo sub-watershed. The terrain consists of around 5% nearly flat areas, 61% wavy to undulating areas, and the rest are mountainous zones. Physiologically, the area is composed of almost 80% volcanic plains, and the remaining part is made up of hills with 16% metamorphic rock, 1.15% sandstone phyllite, and 0.9% limestone sedimentary rock. If the slope is considered, almost 35 % of the area consists of > 15% slopes, namely mountainous areas, volcanic intrusion areas, and

volcanic upper slopes. Meanwhile, the lower slope areas, volcanic plains, or almost flat areas are used for rice fields with little irrigation. Data regarding land use can be seen in **Table 2**.

Table 2. Type and extent of land use in the upper reaches of the Selo watershed, Tanah Datar Regency, West Sumatra

Land Type	Area		Area	
	ha	%	ha	%
Village	1212	8.55		
Paddy field			4125	28.9717
Irigation	889	6.13		
Non-irigation	3236	22.84		
Dryland	196	1.38		
Mixed plantation	4836	34.13		
Plantation	773	5.46		
Forrest	815	5.75		
Shrub	642	4.53		
Others	22	0.16		
total	12621	100		

* Source: [4], [5]

According to the Reforestation Directorate [6], based on the 1: 100,000 scales map, the Selo sub-watershed is a buffer area consisting of rice fields 11923.45 ha (31%), mixed plantations 1072.43 ha (10.4%), cinnamon and rubber 9334.15 ha (27%), dense forest 2971 .94 ha (7.7%), moorland 79.45 ha, scrub 9506.27 ha, reeds 2873.06 ha, and barren land 1045.5 ha.

When mapped using ZAE with a map scale of 1:50,000 [7], the Selo sub-watershed upstream area is categorized as agroforestry of the Wanatani area. This forestry area develops the concept of agriculture, forest, and livestock in one integrated zone. Based on the information presented in Table 1, it is recommended that certain areas be designated as protected areas. These areas include the upper volcanic regions, specifically the upper and middle slope areas of Vab. 1.2.3 and Vab. 1.3.3, as well as some sections of Hg 1.2.3 and Hf 1.2.3.

The sub-watershed is nestled on the lower slopes of Vab. 1.4.2 and Vd. 2.1.2, which comprise a significant 31% of the rice fields in the region. The rice fields span a portion of the lower slope of the Hg 1.2.3 and PtPs or Hf 1.2.3 areas, accounting for 34% of the total area. About 8.55% considers as the residential area, which the village is settled on the outer edge of the volcanic plains. Essentially, the agroforestry area covers all physiographic units, from the hills of metamorphic rock to the expansive volcanic plains.

Additionally, the limestone formation area Kc 1.33, which accounts for less than 1% of the total area, should be reforested since it acts as a protective barrier for the area below it, thereby safeguarding the water resources. Protecting mountainous regions with forest plants is essential for soil and water conservation [8]. Soil conservation is closely linked to water conservation,

which means that planting more trees can help increase the amount of water available in an area. Moreover, forestation can also help prevent soil erosion and landslides.

The region is mostly flat, consisting of volcanic plains, and lacks a water source, which means that the farming methods currently employed by local farmers may not produce the best results. One promising solution is to implement agroforestry or Wanatani, which helps preserve water sources. This study focuses on analyzing land conservation using the Wanatani method. It includes an analysis of the water balance in the Ulu Selo watershed, based on hydrological calculations, predictions of the water shortage period, proposed plants based on available water and water demand, and recommendations for improving land conservation in the surrounding Ulu Selo watershed area.

2 Material and Method

In order to comprehend the notion of Wanatani in the Ulu Selo watershed, a survey method was employed. This method involved comparing the areas where people were planting crops to the government's mass forestry pattern. The approach was more qualitative than quantitative; secondary data, including rainfall and climate data, was also utilized. The secondary data was obtained from various institutions in the Ulu Selo watershed, specifically the Tanah Datar Regency government office. This data was later computed using a particular process, such as the hydrological Thiesen polygon, to fulfill the data unavailable from the survey. Furthermore, the surveyed areas were classified into three groups: rice fields (28.35%), mixed gardens and residential areas (43.68%), and government forestry areas (28%).

The area for the Wanatani was divided into: 1. Mixed plantation areas, including residential areas covering an area of 42.68%, are classified as agroforestry areas. This area covers the physiography of metamorphic hills and upper slopes of intrusive rocks, and Kc is included in the national rehabilitation area.

The forest mentioned here was part of the Mount Marapi Conservation Zone. The Hf and Kc regions are hilly areas that require critical land rehabilitation. This rehabilitation involved converting shrub areas into forest areas as part of an agroforestry program that began in the early 1980s. This program covered both forested and hilly areas and aims to improve the hydrological function of the forest. The evapotranspiration value should be lower than precipitation, allowing water absorption into the soil and groundwater reserves [9], [10]. For the recommendation, when selecting forest plants for Wanatani, one must choose native plants or those that lose their leaves during the dry season, according to the climate in the area.

3 Discussion

As mentioned in the previous section, because there was no rainfall recording station in Sungai Tarab District, Thiesen polygons were used by computing the data from the nearest station[11], namely Salimpauang and Lima Kaum sub-districts, as shown in **Table 3**.

The water balance in the upstream watershed used data from the Salimpaung sub-district, as seen in **Table 4**. With the condition that if the number of rainy days was < 10 days, then the

ETC value = 150 mm, and if the number of rainy days was > 10 days, then the Etc value = 120 mm [9]. Meanwhile, groundwater reserves for one profile were 200 mm [12].

Table 3. Sungai Tarab sub-districts rainfall data from BPP Lima Kaum Tanah Datar Regency, West Sumatra

Lima Kaum		Jan	Feb	March	April	May	June
	Precipitation	203	157	192	185	154	86
	Day	15	11	15	13	12	7
BPP	Precipitation	204	169	235	239	200	121
Salimpaug	Day	15	11	17	16	13	9
	Polygon Thiesen Calculation						
		203	162	211	209	174	101

Lima Kaum		July	August	Sept	Oct	Nov	Dec
	Precipitation	73	76	118	162	207	215
	Day	8	7	13	12	15	17
BPP	Precipitation	93	104	169	185	246	260
Salimpaug	Day	8	9	12	14	25	16
	Polygon Thiesen Calculation						
		82	88	140	172	224	235

Table 4. Water Balance in Salimpaung Sub-district, Tanah Datar Regency, West Sumatra

Month	Precipitation	Days	Etc	Accumulation	Balance	Run-off	m^3/s	l/s
January	225	16	120	425	305	105	0,19	190,80
February	165	11	120	365	245	45	0,08	81,77
March	245	17	120	445	325	125	0,23	227,14
April	245	15	120	445	325	125	0,23	227,14
May	223	14	120	423	303	103	0,19	187,16
June	125	9	150	325	175	-25		0,00
July	92	8	150	267	117	-83		0,00
August	104	9	150	221	71	-129		0,00
September	168	12	120	239	119	-81		0,00
October	173	14	120	292	172	-28		0,00
November	260	15	120	432	312	112	0,20	203,52
December	266	18	120	466	346	146	0,27	265,30
	2291	175	1530			415		0

Rainfall data in Salimpaung 1978-2004

This area will be suitable for cultivating with woody plants such as Surian (*Toona sureni Merr*), and Andaleh (*Morus macroura*); both types of wood can grow in rainfall of range 900-2500 mm per year in climate zones C and D[13]. Besides these two plants, it is also noted that the Jua or Johar plant (*Cassia siamea Lamk*) can also grow well in this area because this plant can grow from 500- 2500mm or in zones D1 to E2. Historically, plants also grew in the jungle on the border between Salimpaung District and Situjuh Lima Nagari District.

In order to maintain productivity during this period, planting wood can be combined with cardamom plants. These plants need protection and are very suitable to be planted under main trees. Cardamom will start to be harvested after it is 1.5 years to 2 years old; the harvest can last for 15 years. In other words, after four cardamom changes, the woody plants will be suitable for cutting.

Another plant that is worth planting is bamboo. Bamboo can grow up to 50 years old and be planted on steep slopes. Bamboo can be harvested after it is five years old and can be used for various household purposes. By-products in the form of bamboo shoots can be used as vegetables, which have economic value. The minimum rainfall for bamboo growth is 1000mm. This plant can grow in all climate zones A, B, C, D, and E. Elevation ranges from 0 m to 1500 m. It means the volcanic mid-slope area can still be used as a bamboo cultivation area. Bamboo is the fastest-growing plant. In a day, it can grow 60cm or 24 inches.

Apart from woody plants that are suitable for growing in the regional climate, the Selo watershed is also suitable for planting with fruit plants, such as candlenut (*Aleurites moluccana*), persimmon (*Diospyros kaki*), cashew (*Anacardium occidentale*), avocado (*Persea americana*), and sapodilla (*Manikara zapota*). All the plants above are fruit plants that can grow well in climate zones D and C to E[14].

The candlenut plant is also known as a primitive plant; this plant can grow in shallow and dry soil and has many uses. The contents of the fruit can be used for cooking, while the shell is rich in the element potassium, meaning that the ash from the candlenut shell can be used in rice planting as a substitute for KCl fertilizer. Candlenuts can be planted on volcanic ridges on upper and middle volcanic slopes that have been incised.

Persimmon is a fruit plant that usually grows in Japan, which already grows in Alahan Panjang. The Japanese army may have brought the seeds in early 1942 or during World War II. Stem cuttings can do plant propagation. Cashew nuts can grow to 1000 m asl with rainfall of 1000 - 3500 mm and dry months of 4-6 months.

According to **Table 5**, the productivity of plantation crops in the Ulu Selo watershed can be improved. While there is a noticeable difference in productivity for sugar cane, cloves, and coconut, the difference is insignificant for coffee plants. Cloves are starting to produce again after being affected by the immature dieback disease (*penyakit mati Bujang*), which caused many farmers to stop planting them. However, coconut production is low due to unfavorable regional conditions. The production of sugar cane is also deficient compared to the reference data. In the past, the Salimpaung sub-district area was famous for producing cane or saka sugar, but in the last two decades, sugar cane planting in the area has decreased significantly. This

condition has led to a reduction in the number of sugar cane farmers, as well as the number of sugar cane mills or saka-making houses.

Table 5. Area and production of plantation crops in the Ulu Selo sub-watershed, Tanah Datar Regency, West Sumatra

	Harvest Area	Production	Production t/ha [15]	reference t/ha [16]
Coconut	91.5	101.48	1.11	3.35
Clove	106.28	25.64	0.24	449
Cocoa	350.5	153.175	0.44	1.15
Betel nut	3	3	1.00	
Sugar cane	287	0.97	0.00	85
Robusta coffee	134.5	80.87	0.60	0.85
Cinnamon	524	75.925	0.14	

The area dedicated to Robusta coffee cultivation is only 134.5 hectares, compared to the 4,836 hectares of land used for mixed plantations. This condition indicates that the coffee planting area needs to be increased significantly. This area's climate is suitable for coffee cultivation, as it is distinctly dry. Historical records show that Rao-Rao was a coffee producer during the Dutch era's cultivation system (*Cultuurstelsel*). Cocoa cannot be grown in this area due to the prolonged wet season, which can result in fungus attacks and pests like squirrels and monkeys. Cinnamon is no longer popular in the area due to its low price per kilogram.

Table 6. Production of fruit plants in the Ulu Selo sub-watershed, Tanah Datar Regency, West Sumatra

	Harvest Area	Production	Production t/ha[15]	Reference t/ha[16]
Avocado	52.93	121.5	2.3	2.25
Papaya	9.58	4.79	49.98	23
Durian	51.32	151.5	2.95	0.83[17]
Sapodilla	1.68	9.5	5.65	0.35[17]
Banana	12.82	10.2	85.84	30

Table 6 shows that banana and papaya production is double and almost triple the reference production, while avocado production is in the same degree. Possibly because papaya and banana are tropical plants; however, this data came from a European perspective, which means the other production, such as Durian and Sapodilla, is lower than the value in the reference.

Table 7. Area and production of food and horticultural crops, Tanah Datar Regency, West Sumatra

	Watershed Upstream area Paddy field area	area	Production t/ha[15]	reference t/ha[16]
Rice	4125	7162.4	5.67	4.5
Corn		1652.3	7.735	7.5
Cassava		133	41.15	35
Peanut		109.8	1.675	1.5
Chili		620	5.14	12.5
Chickpeas		479	7.015	1.25
Sweat potato		114.6	31	15
Cucumber		23	3.16	12
Tomato		50	4.93	15
Eggplant		77	4.74	5

Rice is the primary commodity in the watershed, as can be seen from the percentage of rice fields, which reaches 29% of the area (**Table 7**). Rice fields generally have small-scale irrigation, and planting patterns depend on weather conditions. The area is included in the agricultural climate zone D, namely areas with wet months for four consecutive months and those with dry months for one month and three consecutive months, including D1 and D2, with total rainfall of 2,291 mm for Salimpaung sub-district and 2,048 mm for Sungai Tarab sub-district are corn and peanut plants. Usually, this plant is grown after the rice harvest; therefore, if the rice field area is 4,125 ha, the secondary crops should also be that large. It means that land use could be better in agriculture in the Ulu Selo watershed. Climatically, corn and beans have the exact climate requirements and can grow sufficiently with monthly rainfall of 125-100 mm [16]. Because of this, farmers usually plant corn and peanuts together or through a combination of chilies, corn, and peanuts. From the data, it can be seen that land use has not been maximized.

Table 8 shows that the number of large livestock units in the Selo watershed area is 7,111. If this table is connected to the number of families in the Selo watershed, there are 12,368 families. This condition reflects that not all farmer families own livestock; this comparison shows that 0.57 farmer families own one large livestock. Ideally, a farming family has three livestock units, so if this ideal concept is used, the number of livestock in the Ulu Selo watershed will be 37,104 units ,or five times the current number.

If we take the ratio between the number of farmers' families and the number of goats/sheep, we find something peculiar because the ratio is 0.74, meaning that not all farmer families have goats. Ideally, a farmer's family has a minimum of 5 goats so that the farmer can meet the fertilizer needs of his agricultural area.

Table 8. Number of livestock in the Ulu Selo watershed, Tanah Datar Regency, West Sumatra

Livestock	Number Unit
Cow	6481
Buffalo	630
Goat/Sheep	9099
Horse	2
Poultry	
Chicken	12642
Purebred chicken	
Duck	6200

According to reports, there are only two horses left, which is a very small number. This indicates a decline in public interest in horses. Interestingly, the Selo watershed is located just 5 km away from Fort Vander Capellen in Batusangkar, where there is a horse racing arena. **Table 9** is data on livestock manure, which can contribute nutrients to agroforestry businesses.

Table 9. Nutrient Content in Tithonia and Bucirkam extracts used by farmers at Organic Farming Institute Kenagarian Aie Angek, X Koto District, Tanah Datar Regency

No	Material	N gr/kg	P_2O_5 gr/kg	K_2O meq/	N/m^2 gr/	P_2O_5/ m^2 gr	K_2O /m^2 gr
1	Bucirkam	142.1	1.585	-	31.26	5.578	-
2	Titonia extract	96.6	1.613	-	21.25	5.677	-
3	Chicken manure	9.8	4.3	20.64	13.07	11.8	54.04

The results of the analysis show that by administering 220 ml per 15 days, tithonia or the Bucirkam (goat manure and urine) extract liquid fertilizer contributes 5.6 gr per m^2 P_2O_5, and 500.19 gr N per m^2, or the equivalent of 56 kg P_2O_5 kg per ha and 250 kg N available. The P value was calculated using the Bray II method based on the available value. In contrast, the available N is estimated to be 5% of the total N value in liquid fertilizer.

Farmers of the Organic Farming Institute (*Institute Pertanian Organik*/IPO) have provided highly nutritious tithonia and Burcirkam extracts. The nutrient content in these extracts is higher than the nutrients lost in the plants. Before using the liquid, it should be diluted with water in a ratio of 1:3. By administering 2,640 ml or 2.6 liters of the diluted extract 12 times per clump of plants, and the plants will receive 168 kg P_2O_5 kg per ha and 750 kg N available per ha of nutrients. Referring to the soil analysis with conventional pattern treatment, available P ranges from 2.65 kg P_2O_5 per ha to 34 kg P_2O_5/ha in the top layer. To improve the condition of soil that has long been used as conventional agricultural land, like the land at IPO Aie Angek, tithonia and Burcirkam extracts should be provided to each plant at a rate of 220 ml per plant every 15 days, 12 times per growing season. Routine provision every three weeks is recommended for polyculture systems.

4 Conclusion

Based on the discussion, it was concluded several critical points. The Agro-Economic Zone in the Ulu sub-watersheds of the Selo watershed was suitable for the Wanatani concept, as shown on a 1:50,000 scale map. Around 34% of the area was covered by a mixed garden, which can apply the Wanatani concept by using native woody plants like Surian (*Toona sureni Merr*), Andaleh (*Morus macroura*), Jua or Johar (*Cassia siamea Lamk*) and fruit plants like candlenut (*Aleurites moluccana*), persimmon (*Diospyros kaki*), cashew (*Anacardium occidentale*), avocado plant (*Persea americana*), and Sapodilla (*Manikara zapota*). Other crops which suitable to grown here are coffee (*Coffea sp*) and durian (*Durio zebetinus*).

From the survey and data analysis, this area will experience a water deficit during June, July, August, September, and October, with a total water deficit of 329 mm. Pine trees cover around 28.35% of the area and cause a water deficit of 11,771,796 m^3 because they did not shed leaves in the dry season. This water deficit was equivalent to 11,771,796,015 m^3 of water in an area of 3578 ha or 28.35%. As a result, river discharge will be reduced by 0.32 l/sec/yr, and if this continues for 25 years, the discharge will be reduced to 8 l/sec. It could lead to water shrinkage in the flow area that leads to the Batang Selo River. It includes Batang Aie Banda Gadang River, which is 6.5 km long; Batang Selo River, 4 km long; and Batang Sumanik River, which originates from Rao-Rao and flows into Sumanik for 3 km. It is worth noting that several lakes could potentially be impacted.

Finally, the use of goat and chicken manure is beneficial in replenishing nutrients extracted by plants. Additionally, buffalo and cow manure can be used not only as a fertilizer but also as a source of energy. By raising five goats per family of farmers, liquid organic fertilizer from their manure can be used as a means of watering plants, which in turn can help reduce water shortages from June to October.

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