# Establishment of Agrotechnological Model Based on the Analysis of Change Impacts on Land Use the Wanggu Watershed in Southeast Sulawesi, Indonesia

**La Ode Alwi**
Lecturer
Department of Agrotechnology
Faculty of Agriculture
Haluoleo University
Southeast Sulawesi, Indonesia

## Abstract

***Establishment of Agro technological Model Based on the Analysis of Change Impacts on Land Use the Wanggu Watershed in Southeast Sulawesi, Indonesia.*** *Land degradation and hydrological conditions of the Wanggu watershed were assessed based on changes in land use, soil physics, erosion and surface runoff coefficient and river discharge using survey methods and experimental plots. Data of land biophysics included climate data, topography, soil types, and land use obtained from the results of various studies. Farmers' income was calculated based on total production, revenues, and total cost spent by farmers. The research was conducted from January 2015toJune 2015. The aims of the research were (1) to assess the impacts of changes in land use in the Wanggu watershed in terms of erosion, land degradation, discharge ratio of* $Q_{max}/Q_{min}$*, and farmers' income from farming; (2) to analyze land use and models of agrotechnology that could not only improve soil infiltration capacity and water availability, but also reduce discharge ratio (*$Q_{max}/Q_{min}$*) and erosion rate and land degradation; and (3) to formulate a model of land use planning and agrotechnology in sustainable watershed management. The study result showed that the changes in land use that were not in accordance with land capability had led to land degradation, generally on dry fields, shrubs, and settlements with erosion> Etol, respectively 38.0>16.7; 20.3> 11.6 and 15.9> 15.6 tons/ha/yr) on a slope of > 8%.In the meantime, the increase in discharge ratio (*$Q_{max}/Q_{min} > 30$*), land productivity and farmers' income was low (dry land agriculture Rp 21,500,000* $ha^{-1}yr^{-1}$*, and mixed farm/agroforestry Rp 31.5 million* $ha^{-1}yr^{-1}$*<decent standard of living need (SLN) which was Rp 32 million* $yr^{-1}$*/household. The model of land use and agrotechnology of scenario-4 (34.0% forest, 15.2% settlement, 39.8% mixed farm + Agrosilvopastoralperennial crops and 11.0% dry land + cropping pattern)was to prevent land degradation with erosion 10.1 tons* $ha^{-1}yr^{-1}$*< TSL 12.1tons* $ha^{-1}yr^{-1}$*, lower the discharge ratio (*$Q_{max}/Q_{min}$*18.5 <30), improve soil productivity and enhance farmer income from Rp 32.34 million to35.73 million ≥ Rp 32,000,000* $ha^{-1}yr^{-1}$ *per household (SLN in Southeast Sulawesi).*

**Keywords:** *land use, the Wanggu watershed, impact, erosion, agricultural system.*

## *1. Introduction*

Changes in land use in the Wanggu watershed for the last 21 years have had impacts on land degradation and the disruption of hydrological conditions and sedimentation along the Wanggu watershed in Kendari bay. The changes in the upstream (in site) were the conversions of forestlands to farmlands, farmlands to non-farmlands, reducing the forestlands. The impact was erosion>tolerable soil loss (TSL) (55.3 tons$ha^{-1}yr^{-1}$> 32.7 tons $ha^{-1}$ $yr^{-1}$), declining the production of cocoa from 2 tons $ha^{-1}yr^{-1}$ to 0.75 tons $ha^{-1}yr^{-1}$, gogo rice from 1.6 tons $ha^{-1}yr^{-1}$to 0.9 tons $ha^{-1}yr^{-1}$, corn from 2 tons $ha^{-1}yr^{-1}$to 1.2 tons $ha^{-1}yr^{-1}$(Marwah, 2000). The erosion had caused the silting of the irrigation canals, water bodies, wetlands, and environmental damage in Kendari bay. In addition, there was an increase in the water discharge of the Wanggu River (Qmax /Qmin > 30) to a flood height of 3.5 to 4 m (Sultra's Public Works Agency, 2008). Similarly, there was an increase in sedimentation in Kendari bay from 1995-2000 amounting to 760,040 $m^3$ $yr^{-1}$, and in 2000, the depth of Kendari bay was in the range of 0-23 m measured at high tide (Iswandi, 2003). In 1992, the forestlands in the Wanggu watershed covered 19,554.2 ha, in 2000 17,278.2 ha, and in 2005 14,593.8 ha (BPDAS Sampara, 2008). The changes of forestlands into agricultural lands were generally not in accordance with the land capability. As a result, land degradation occurred that was characterized by: (1) the high erosion > Tolerable Soil Loss (TSL), (2) the decrease in infiltration capacity, (3) the increased runoff, (4) the occurrence of floods in the rainy season and drought in the dry season, (5) sedimentation, (6 ) the decrease in land productivity, lowering farmers' income.

A number of studies have shown that the conversion of forestlands reduced soil quality but it could increase again by leaving the land fallow, applying a proper soil conservation or cocoa agroforestry system (Marwah 2008 and Anas et al., 2005). The study by Lihawa (2009) showed that wasteland affected the environmental conditions of the Alo-Poha watershed in terms of water discharge and drainage. Additionally, it also had a significant effect on sheet erosion by 122.24 tons $ha^{-1}yr^{-1}$.The Wanggu watershed DS covering an area of 45,377.3 ha has strategic functions and roles because its flows divide the city of Kendari, the capital of Southeast Sulawesi province in the downstream, which is the center of government, education and economy, industrial area, source of clean water for Cialam Jaya transmigration residents and many of Kendari city residents, and water irrigation of 3,500 ha of rice fields in the sub-districts of Konda, Poasia and Ranomeeto. The upstream part is the territory in the regencies of Konsel and Konawe, and in the middle are Wolter Monginsidi Airfield and sand mining.

To maintain its strategic functions and vital roles, it is necessary to be supported by the planning of appropriate land use and agrotechnology for the preservation of lands, water resources in the Wanggu watershed and sedimentation prevention. Until now there has been no proper land use planning and agrotechnology in the Wanggu watershed related to land preservation, long-term water resources, and sedimentation prevention. This would lead to land degradation, erosion and high runoff, low infiltration capacity, floods in the rainy season, drought in the dry season, water scarcity, and high sedimentation (Sinukaban, 2007).The study objectives were: (1) to analyze the impacts of changes in land use in the Wanggu watershed DS against erosion, runoff and fluctuation of water discharge, (2) to examine the model of land use and agrotechnology that could improve soil infiltration capacity, decrease runoff, fluctuation of river water discharge, erosion rate, and increase farmers' income, and (3) to formulate a model of land use planning and proper agrotechnology for the sustainable management of the Wanggu Watershed.

## *Materials and Methods*

### Location and Time

The research was conducted in the Wanggu watershed $_{DS}$ covering 45,377.3 hectares in two regencies (Konaweha, Konsel) and Kendari city of Southeast Sulawesi Province, which is located at $3^0$ 59' 23"- $4^0$ 10' 14" south latitude and $122^0$ 22' 26 "- $122^0$ 33'14" east longitude (Figure 1) from January2015 toJune 2015.

### Materials and tools

The materials needed in this study were as follows: a map of earth face of Indonesia on Southeast Sulawesi in 1992 from Bakonsurtanal, soil map of Southeast Sulawesi in 1985 (PPT, Bogor), interpretation of Landsat imagery of Southeast Sulawesi in 2010 (Bakonsurtanal), Image interpretation of Kendari bay in 2015 (primary data), the data of rainfall, water discharge obtained from the Regional Institute of river 4 SULTRA, the water quality obtained from Public Works Agency and Environment Institute of SULTRA, and population (BPS SULTRA). The materials included land use, topography, soil types, Landsat imagery, paper and plastic bags. The tools used were Clinometer, soil drill, soil profile blade, ring sample, meter roller, stopwatch, infiltrometer with double cylinder, permeameter, GPS, AWLR, ARR and bottled water sample.

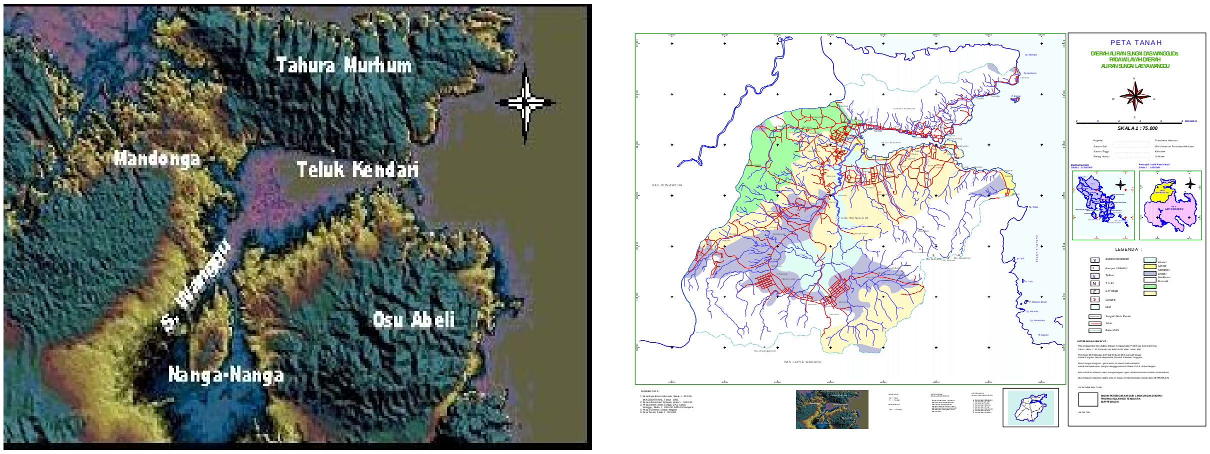


**Figure 1: Research Site (the Wanggu Watershed Ds)**

## *Research Methods*

This study used survey method, observation plots, field observation, laboratory analysis, and interviews with respondent farmers.

## *Determination of Observation Plot*

Determining an observation location was made based on the unit map of land and watershed representative, namely the Wanggu watershed (purposive sampling), for sample placement of intensive observation on erosion and runoff. The observation plot was 6 m by 4 m set by Group Random Design (GRD). Types of land use as treatments were symbolized by T1 (mixed farm), T2 (shrubs / reeds), T3 (dryland agriculture / dry field), T4 (settlement) and T5 (forest) as a control. Observation plot arrangement in the field was tailored to the type of land use in the Wanggu watershed, consisting of the mixed farm as treatment T1, shrubs / reeds as treatment T2, dryland agriculture, / dry field as treatment T3, settlement as treatment T4, and forest as treatment T5. Of all the treatments, three classes of slope were determined as a group, namely 8% (K1), 15% (K2) and 25% (K3) so that there were 15 combined treatments. To determine the influence of land use, this research used the test of $F_{\alpha 0.05\,/\,0.01}$ and if F hit was > F $\text{table}_{\alpha 0.05/0.01}$, it would be continued with a test between treatments using the test of Least Significant Difference $(\text{LSD})_{\alpha 0.05\,/\,0.01}$.

The plots of erosion and runoff observations were made of plastic zinc. At the bottom of the slope in each plot was a container that served to collect soil erosion and runoff. The measurement of eroded soil and runoff was done each morning. The sample of the eroded soil collected in the container was as much as 1 liter after having been homogenized for the purpose of analysis in the laboratory using the gravimetric method. The runoff volume was calculated by measuring the runoff water collected in the container.

## *Data collection*

To assess and evaluate the condition of the land due to the impact of the dynamics of land use in the Wanggu watershed on land degradation and hydrological condition of the Wanggu watershed $_{DS,}$ this research used the data of changes in land use in 1992, 1995, 2000, 2005, 2010 and 2015 years) including changes in forest cover, shrubs and reeds, mixedfarm, dry field and settlement (secondary data). Land degradation was assessed by comparing the predictive value of erosion (1992-2014), the actual erosion (2015) with the tolerable soil loss (TSL) (erosion >TSL). Hydrological conditions that were analyzed included infiltration, surface runoff, runoff coefficient, $Q_{max,}$ $Q_{min}$ and $Q_{max}/Q_{min}$ (KRS). The income of farmers in the upper Wanggu watershed was assessed based on (income = total income - total expenses) the entire farming activities.

The data collected consisted of: (1) the characteristics data of Ultisol soil: texture, structure, soil porosity, soil organic matter, bulk density, specific weight of soil, (2) hydrological data: permeability and soil infiltration, evapotranspiration, initial soil moisture, field capacity, discharge, $Q_{max}$ / $Q_{min}$, and rainfall for 6 months (January 2015 - June 2015, the primary data), (3) land biophysics: topography (shape and slope), the type of soil (generally *Ultisol*), climate, the land use for the last 27 years, and the data of water discharge of the Wanggu river.

Alternative models of changes in land use in the Wanggu watershed $_{DS}$ were based on **scenarios**, as follows: **Scenario 1:** the current condition of the Wanggu watershed, **Scenario 2**: S-1 + changing 100% scrub-thatch (SB-I) into forest 34,0% (minimum forestland is 30% of the watershed (Law No. 26/2007 on Spatial Planning, Article 17, paragraph 5), **Scenario 3**: S-2 + cropping pattern on dry field, **Scenario 4:** Scenario3 +*Agrosilvopastoral perennial crops* with pasture on mixed farms (Table 1).

In each of the alternative model developments (scenarios), the amounts of erosion were estimated using USLE method (A = RKLSCP), including the volume of runoff in the every event of precipitation (7.6 mm / dd) which caused runoff for 1 year. The method used was SCS method (Arsyad, 2010). To determine the best scenario, this study used the criteria of erosion < TSL where the fluctuations in discharge rate had to be ($Q_{max}$ / $Q_{min}$) < 30. Out of the 4 (four) scenarios, the amount of farmer income was calculated until it could achieve the minimum physical needs (Sajogyo, 1977) and decent standard life needs (SLN).

**Table 1: Model of Scenarios of land use in the Wanggu watershed in 2015**

| **PL** | **S1 (ha)** | **S2 (ha)** | **S3 (ha)** | **S4 (ha)** |
|---|---|---|---|---|
| Mixed farm (T1) | 18,082.5 | 18.082.5 | 18,082.5 | **18,082.5+*Ag*** |
| SB/I (T2) | 7,299.5 | 0 | 0 | 0 |
| Dry field (T3) | 4,976.9 | 4,976.9 | **4,976.9+Pt** | **4,976.9+Pt** |
| Settlement (T4) | 6,894.8 | 6,894.8 | 6,894.8 | 6,894.8 |
| Forest (T5) | 8,123.6 | **15,423.1** | **15,423.1** | **15,423.1** |
| ∑ | 45,377.3 | 45,377.3 | 45,377.3 | 45,377.3 |

**Note:** KC = mixed farm, SB/I = shrubs/Reeds, Pt = cropping pattern (Jg+Kd+Cb), Ag = Agrosilvopastural-prennual crops with pasture

## *Results and Discussion*

### Changes in Land Use in Wanggu Watershed

Changes in land use are one of the important factors that determine watershed ability in response to the input of rain water into the watershed. Another important factor is the condition of the soil (soil type, physical properties, topography and other soil properties), agrotechnology and land management. The change in land use that does not comply with its ability will affect the hydrological condition, declining soil fertility and causing land degradation. Sinukaban (2008), and Marwah and Alwi (2014) state that land degradation and the destruction of hydrological functions of a watershed are caused by many factors, among others: (1) land use and land purpose that deviate from the Spatial / Regional Plan, (2) land use which is not according to its ability, (3) no soil technical conservation and water conservation applied to steepslope cultivation, (4) the absence of regulations governing firmly, and (5) lack of government commitment to the arrangement of land use.

The changes in land use in the Wanggu watershed in the period 1992-2015 (Table 2) showed that there was a 25.3% decrease in forestlands (-11,430.6 ha) and shrubs -19.8% (-8,996.9 ha). Meanwhile, there was an increase in large mixed farms, dry field / rice field, and settlement, respectively +25.8% (+11,725,0ha)(T1), +9.7% (+4,407.9 ha)(T4), and +9.4% (+4,294.6 ha)(T3). The annual average change for each type of land use was as follows: mixed farm increased by +1.0% (+434.4 ha)(T1), scrubs / weeds decreased by -0.7% (-408.5 ha)(T2), dry field / rice field increased by +0.4% (+163.3 ha)(T3), settlement increased by +0.3% (+159.1 ha)(T4) and forest decreased by -0.9% (-423.4 ha)(T5). This is due to the increased needs for food, shelter, and infrastructure of urban/rural areas of the Wanggu watershed.

**Table 2: Changes in land use in the Wanggu watershed Ds in the period 1992-2015**

| Pe | T1 | | T2 | | T3 | | T4 | | T5 | Δ |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ha | % | Ha | % | Ha | % | Ha | % | Ha | % |
| 1992 | 6,357.5 | 14.0 | 16,296.4 | 35.9 | 569.0 | 1,3 | 2.600,2 | 5,7 | 19.554,2 | 43.2 |
| 1995 | 10,366.6 | 22.8 | 11,489.8 | 25.3 | 1,210.2 | 2,7 | 3.681,8 | 8,1 | 18.628,8 | 41.1 |
| 2000 | 11,908.4 | 26.2 | 6,518.0 | 14.4 | 4,308.4 | 9,5 | 5.364,3 | 11,8 | 17.278,2 | 38.1 |
| 2005 | 14,832.8 | 32.7 | 4,415.4 | 9.7 | 5,774.1 | 12,7 | 5.761,2 | 12,7 | 14.593,8 | 32.2 |
| 2010 | 15,585.8 | 34.3 | 9,342.0 | 20.6 | 4,022.4 | 8,9 | 5.959,3 | 13,1 | 10.467,8 | 23.1 |
| 2015 | 18,082.5 | 39.8 | 7,299.5 | 16.1 | 4,976.9 | 11,0 | 6.894,8 | 15,1 | 8.123,6 | 17.9 |
| ∑ Δ | 11,725.0 | 25.8 | -8,996.9 | -19.8 | +4,407.9 | +9.7 | +4,294.6 | +9.4 | -11,430.6 | -25.3 |
| **R** Δ | +434.3 | +1.0 | -333.2 | -0.7 | +163.3 | +0.4 | +159.1 | +0.3 | - 423.4 | -0.9 |

**Note:** ∑ = Sum, Δ = Land use changes, R = Average of land use changes, T1 = Mixed farm, T2 = Shrubs, T3 = Dry field/rice field, T4 = Settlement, T5 = Forest.

The Wanggu watershed is a priority watershed in Southeast Sulawesi province due to its strategic location, where: (1) in the upstream part there are forested areas, ex-transmigration of Java, West Java and Bali as well as the spontaneous transmigration from Bugis Makassar who cultivate mixed farms, dry fields, and rice fields; (2) in the middle there are airfield Wolter Monginsidi, rice fields, dry fields, mixed farms and settlement; and (3) in the downstream there is the city of Kendari, in which for the last 10 years there have been the development of significant infrastructure such as the widening of state roads, provincial roads and regency / city roads, construction of new roads, the expansion of the airfield, settlements, shopping center, educational areas, industrial areas, etc.

## *Land Characteristics and HydrologicalIndicators*

### Land Characteristics

The test result of $LSD_{\alpha 0.01}$ of land characteristics in a variety of land use in the Wanggu watershed in 2015 showed a significant difference in the weight of parameters (BV), porosity (Pr), soil organic matter (BO), land cover (PER), potential interception (PIT) and surface roughness (RC) (Table 3).Table 3 shows that the use of forestland (T5) provided Bv which was lower and significantly different from the other land uses except T2. Furthermore, T5 produced Pr, BO, PER and RC which were higher and significantly different from the other land uses. The mixed farm (T1) was not significantly different from shrubs (T2) and dry field / irrigated rice field (T3) but significantly different from the settlement (T4). This shows that forestland has a great influence on the various parameters of the physical characteristics of the land, and the land characteristics greatly affected the hydrological characteristics, especially in lowering the amount of surface runoff (RO), the surface runoff coefficient (CRO) and $Q_{max}$ / $Q_{mi}$n of a watershed.

According to Sinukaban (2007), Asdak (2007), Alwi et al. (2011) and Black (1996) the physical properties of soil such as volume, weight, porosity, soil organic matter, depth of soil profile, land cover, potential interception, and surface roughness affected the infiltration capacity, soil permeability, runoff coefficient, surface runoff and erosion prevention. Furthermore, Marwah (2008) states that forest and Agroforestry have organic matter and soil porosity which are higher compared to the other land uses, thereby reducing runoff and erosion.

**Table 3: Characteristics of Ultisol Soil in 2015 in the Wanggu Watershed**

| **Land use** | **BV ($g/cm^3$)** | **Pr (%)** | **BO (%)** | **PER (%)** | **PIT (mm/yr)** | **RC** |
|---|---|---|---|---|---|---|
| Mixed farm (T1) | 1.45 bc | 44.7 b | 3.81 b | 60.89 b | 102.89 b | 0.46 b |
| Shrubs (T2) | 1.40 ab | 38.2 ab | 3.72 b | 59.92 b | 106.27 b | 0.41 b |
| Dry field/rice field (T3) | 1.44 ab | 41.5 bc | 3.61 b | 59.47 b | 72.02 c | 0.44 b |
| Settlement (T4) | 1.60 a | 34.1 a | 1.10 c | 36.50 c | 21.00 d | 0.31 c |
| Forest (T5) | 1.24 c | 49.0 c | 4.55 a | 84.57 a | 244.00 a | 0.54 a |
| LSD $\alpha_{.01}$ | 0.18 | 6.12 | 0.46 | 6.24 | 5.78 | 0.06 |
| Household (%) | 3.16 | 7.10 | 12.71 | 7.35 | 7.13 | 11.73 |

**Note:** BV = weight of soil volume, BO = soil organic matter, PER = land cover, PIT = interception potential, Pr = porosity, RC = surface roughness

### Hydrological indicators

The test of $LSD_{\alpha 0.01}$ on hydrological indicators of various land uses in the Wanggu watershed in 2015 showed a significant difference in the parameters of field capacity, infiltration capacitance, soil permeability, initial soil water level, surface runoff and surface runoff coefficient (Table 4). Table 4 showed that the forest (T5) provided the value of field capacity (FP), infiltration rate (Inf), higher permeability (PP), followed by mixed farm (T1), dry field / irrigated rice field (T3) which were significantly different from shrubs (T2) and settlement (T4), but not significantly different from a dry field (T3). Furthermore, T5 and T1 lowered surface runoff (RO), the coefficient of surface runoff (CRO) which was significantly different from shrubs (T2), dry field (T3) and settlement (T4).

**Table 4: Hydrological Indicators in 2015 in the Wanggu watershed**

| Type of Land Use | FP (% KA) | Inf (cm/hour) | PP (cm/ hour) | RO (mm/year) | CRO |
|---|---|---|---|---|---|
| Mixed farm (T1) | 41.81 b | 6.00 b | 4.50 b | 364.2 d | 0.19 ab |
| Shrubs (T2) | 46.81 b | 3.92 b | 3.32 c | 432.1 c | 0.23 b |
| Dry field/rice field (T3) | 53.15 ab | 5.32 ab | 3.10 cd | 617.5 b | 0.33 c |
| Settlement (T4) | 35.50 b | 4.12 b | 2.30 d | 814.5 a | 0.44 d |
| Forest (T5) | 73.60 a | 6.67 a | 5.43 a | 267.2 e | 0.15 a |
| LSD$\alpha_{0.05}$ | | | 2.53 | | |
| LSD$\alpha_{0.01}$ | 0.40 | 0.83 | | 46.71 | 0.07 |
| Household (%) | 8.50 | 13.82 | 12.37 | 11.1 | 10.54 |

**Note:** FP = Field capacity, Inf = infiltration rate, PP = permeability profile, RO = surface runoff, CRO = surface runoff coefficient

The lowest RO result was 267.2 mm / yr and CRO 0.15 in the forest (T5), followed by mixed farm (T1) with an RO of 364.2 mm / yr and CRO 0.19. In contrast, the highest RO and CRO were generated by (T4) which were 814.5 mm / yr and 0.44, followed by T3 with RO as high as 617.5 mm / yr and CRO 0.33, T2 with an RO of 432.1 mm $yr^{-1}$ and CRO 0.23. It has been argued by Chang (2002), Asdak (2007) and Black (1996) that forests have an important role in the physical properties of the soil such as volume weight, porosity and soil organic matter, depth of soil profile, land cover, potential interception, surface roughness affecting infiltration capacity, soil permeability, runoff and surface runoff coefficient. The functions of forests and agroforestry are also very important in maintaining the stability of the watershed ecosystem (ecological function), mainly as a catchment area (recharge area) which serves to maintain the stability of the hydrological cycle, economic and social functions in the communities around the forest and agroforestry.

Table 5 shows that the erosion of T5 differs from T1, and T1 is significantly different from T2, but not significantly different from T3 and T4. The highest erosion was reached in T3 followed by T4. The amount of erosion in the T3 and T4 was caused by the amount of RO resulting in greater erosion in Etol, while in T5, T1 and T3 the erosion was smaller (erosion <Etol). The erosion < ETol in T3 and T4 will cause degradation of the study sites, especially in dry land (T3) and settlement (T4). Land use that does not use agro-technology (soil and water conservation) will accelerate land degradation and marginalize each other between the land and the farmers (Sinukaban, 2007).

**Table 5: Eros, Etol and its comparison measurement from January 2015toJune 2015 in the Wanggu watershed**

| Type of Land Use (TLU) | Erosion (tons/ha/yr) | TSL (tons/ha/yr) | Comparison Erosion | TSL |
|---|---|---|---|---|
| Mixed farm (T1) | 10.4 b | 17.1 | | < |
| Shrubs (T2) | 15.9 bc | 15.6 | | < |
| Dry field/rice field (T3) | 38.0 e | 16.7 | > | |
| Settlement (T4) | 20.3 cd | 11.6 | > | |
| Forest (T5) | 3.8 a | 16.4 | | < |
| Average | 17.6 | | | |
| LSD $\alpha_{0.01}$ | 6.2 | | | |
| Household (%) | 14.1 | | | |

**Note:** The figures in the same column which are followed by the lame letters were not significant in the test of LSD$\alpha_{0.01}$.

### *Impacts of Land Use Changes on Hydrological Conditions*

Changes in land use have an impact on erosion and hydrological conditions in the Wanggu watershed in the period 1992-2015 which included: runoff, runoff coefficient, maximun discharge, minimum discharge and $Q_{max}/Q_{min}$(Table 6). Table 6 showed that erosion (A), runoff (RO), surface runoff coefficient (CRO), maximum discharge ($Q_{max}$), minimum discharge ($Q_{min}$) and $Q_{max}$ / $Q_{min}$ simultaneously increased from time to time with the average erosion of 24.9 tons/ha/yr, RO (696.1 mm/yr), CRO (0.4), $Q_{max}$ (26.3 m3/sec), $Q_{min}$ (0.9 m3 / sec) and $Q_{max}/Q_{min}$ 31.4.

**Table 6: Changes in land use in the hydrological conditions in the Wanggu watershed –$_{DS}$**

| Parameter | Changes in Land Use in the Period | | | | | | Average | Δ P |
|---|---|---|---|---|---|---|---|---|
| | 1992 | 1995 | 2000 | 2005 | 2010 | 2015 | | (%) |
| A (ton/ha/yr) | 15.5 | 20.3 | 23.5 | 26.7 | 28.2 | 35.4 | 24.9 | 128.4 |
| RO (mm/yr) | 538.6 | 554.2 | 607.3 | 632.9 | 801.3 | 1,042.4 | 696.1 | 93.5 |
| CRO | 0.28 | 0.29 | 0.31 | 0.33 | 0.41 | 0.6 | 0.4 | 114.3 |
| $Q_{max}$ ($m^3$/dt) | 19.34 | 20.32 | 24.38 | 27.36 | 28.76 | 37.4 | 26.3 | 93.4 |
| $Q_{min}$ ($m^3$/dt) | 0.78 | 0.78 | 0.84 | 0.86 | 0.86 | 1.2 | 0.9 | 53.8 |
| $Q_{max}/Q_{min}$ | 24.83 | 26.91 | 29.02 | 32.17 | 33.37 | 42.3 | 31.4 | 70.4 |

**Note:** RO = surface runoff, CRO = coefficient of surface runoff, $Q_{max}/Q_{min}$ = rasio off maximum and minimum discharges, Δ P = change rate

This was caused by the changes in land use, which were not proportional, particularly a decrease in a forested area of -423.4 hayr$^{-1}$ (-0.9%) or-11,430.6 ha (-25.3%), an increase in settlement by +159.1 ha yr$^{-1}$ (0.3%) or +4,294.6 (9.4%) and dry field +163.3 ha yr$^{-1}$ (+0.4%) or +4,407.9 ha (+9.7) of the watershed size. For a 27 year period, there has been an increase in the value of erosion (A) 128.4%, runoff (RO) 93.5%, surface discharge coefficient (CRO) 114.3%, $Q_{max}$ 93.4%, $Q_{min}$ 53.8% and $Q_{max}$ / $Q_{min}$ 70.4% (Table 6, column Δ P). This is consistent with the research results by Handayani, Jayadi and Triatmosemadjo (2005) in the upstream Ciliwung watershed, stating that the reduction in forest cover reached 4.897 ha (18.1% of the watershed size) in 1989 to 4,459 ha (16.2% of the watershed size) in 1998, which turned out to increase the peak discharge and runoff volume, respectively by 18.9% and 18.8%.

The impacts of changes in land use (mixed farms, shrubs, dry fields /rice fields, settlements and forest) were correlated significantly with the increase in RO, CRO and $Q_{max}$ / $Q_{min}$ from year to year (Figure 2). Figure 2 showed that the dynamics was correlated significantly to improve RO with r = 0.929, CRO with r = 0.951 and $Q_{max}$ / $Q_{min}$ with r = 0.990. This showed that the dynamics of land use (mixed farms, shrubs, dry fields, settlements and forest) was not proportional, particularly forest size against the watershed size, and had a significant correlation with the increase in discharge fluctuations that affected the hydrological conditions in the study areas. This is in accordance with what has been stated by Asdak (2007), Black (1996) and Alwi et al. (2011) that forest has an important role in determining the infiltration capacity, soil permeability, runoff and surface runoff coefficient and has an effect on the ratio of the maximum and minimum discharge. The research conducted by Handyani, Jayadi, and Triatmodjo (2005) in the upstream Ciliwung showed that the reduction in forest cover from 18.1% in 1989 to 16.2% in 1998 led to an increase of peak discharge by 18.9% and flood volume by 18.87%. This is to show that the reduction of forest size significantly affects the amount of RO, CRO and $Q_{max}$: $Q_{min}$.

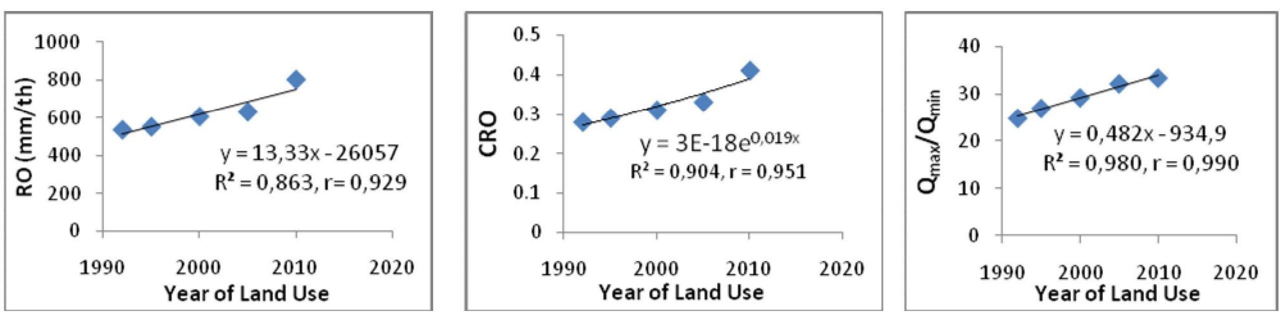


**Figure 2: Correlation of the change time in land use with RO, CRO and $Q_{max}$ / $Q_{min}$**

## *Alternative Analysis of Land Use Development in Wanggu watershed*

### Feasibility Analysis of Ecology

Any alternative development of land use applied to Wanggu watershed-$_{DS}$is to be tested to see its feasibility based on the ecological scenario. The dynamics of land use in each scenario are used to estimate the magnitude of erosion and TSL (Tolerable soil loss), maximum discharge ($Q_{max}$), minimum discharge ($Q_{min}$) and fluctuations in discharge rate ($Q_{max}$ / $Q_{min}$). The dynamics of land use in each scenario are presented in Table 7, where the relation between scenario (S) of land use and erosion and Etol can be seen.

This table showed that erosion was <TSL S4 (forest 8,123.6 ha = T5, mixed farms 18,082.5 ha = T1, dry field4,976.9 ha + cropping pattern = T3 and settlement 6,894.8 ha = T4, S5 = S4 + *Agrosilvopastoral perennial crops pasture*.

Furthermore, the estimation results of the amount of $Q_{max}/Q_{min}$ showed that the scenarios of changes in land use with scenarios S2, S3, and the use of cropping pattern of dry land (S4) as well as Agrosilvopastoral in the mixed farm (S5) have been able to reduce $Q_{max}$ / $Q_{min}$<30.This indicates that the scenarios of changes in land use from shrubs to the forest, dry fields and mixed farms, as well as the application of agro-technology, have been able to preserve the land resources of land and water. In contrast, indiscriminate deforestation in the upper watershed could lead to the disruption of the distribution of the river flow in the downstream (Sinukaban, 2007). In addition, inappropriate changes in land use and / or application of agro-technology that does not fit can cause erosion and increase surface runoff, accelerating the degradation of the upstream land of the watershed and downstream sedimentation in the watershed (Alwi and Marwah, 2014).

Although scenarios S2, S3 and S4 had produced $Q_{max}$ / $Q_{min}$ < 30, the scenarios were not safe to maintain erosion andsoil fertility since land use and agrotechnology in such scenarios had not provided additional input of manure to generate sustainable land management. Scenario S5 (mixed farm 16,557.2 ha + Agrosilvopastoral (cocoa, oranges, bananas, teak, elephant grass and grass for livestock + 3 head of cattle / household) = T1, without shrubs = T2, dry land 4,976.9 ha + *cropping pattern*(corn + soybean + chili pepper) = T3, settlement 6,894.8 = T4, and forest 15,423.1 ha = T5) was the best alternative development with an erosion level of 10.1 tons $ha^{-1}yr^{-1}$< TSL 12.1 tons $ha^{-1}yr^{-1}$and $Q_{max}$ / $Q_{min}$ 18.5 < 30.

**Table 7: Scenario Model of land use (S) in the Wanggu watershed in 2015**

| | S1 | | S2 | | S3 | | S4 | |
|---|---|---|---|---|---|---|---|---|
| TLU | (ha) | % | (ha) | % | (ha) | % | (ha) | % |
| T1 | 18,082.5 | 39.8 | 18,082.5 | 39.8 | 18,082.5 | 39.8 | 18,082.5+Ag | 39.,8 |
| T2 | 7,299.5 | 16.1 | - | - | - | - | - | - |
| T3 | 4,976.9 | 11.0 | 4,976.9 | 11.0 | 4,976.9+Pt | 11.0 | 4,976.9+Pt | 11.0 |
| T4 | 6,894.8 | 15.1 | 6,894.8 | 15.2 | 6,894.8 | 15.2 | 6,894.8 | 15.2 |
| T5 | 8,123.6 | 17.9 | **15,423.1** | 34.0 | **15,423.1** | 34.0 | 15,423.1 | 34.0 |
| ∑ | 45,377.3 | 100 | 45,377.3 | 100 | 45.377,3 | 100 | 45,377.3 | 100 |
| | Erosi Vs Etol | | | | | | | |
| Erosi* | 35.4 | > | 13.3 | > | 15.6 | > | 10.1 | < |
| Etol* | 12.1 | | 12.1 | | 12.1 | | 12.1 | |
| RO** | 1,042.4 | | 453.2 | | 461.6 | | 410,.9 | |
| CRO | 0.6 | | 0.24 | | 0.23 | | 0.21 | |
| $Q_{max}$ | 37.4 | | 28.5 | | 29.1 | | 27.8 | |
| $Q_{min}$ | 1.2 | | 1.4 | | 1.2 | | 1.5 | |
| **$Q_{max}$ : $Q_{min}$** | 42.3 | | 20.4 | | 24.2 | | **18.5** | |

**Note:** * = ton $ha^{-1}yr^{-1}$, ** = mm $yr^{-1}$, T1=mixed farm, T2=shrubs / reeds, T3=Shrubs/reeds, T4=Settlement, T5= Forest, P = cropping pattern (Jg+Kd+Cb), Ag = Agrosilvopasturalprenual crops (cocoa, orange, teak, banana, grass for cattle)

**Evaluation of Agrotechnology Suitability**

Results of the evaluation of the application suitability of agro-technology for farmers in the study area were based on the class of land capability (KL), land use (LU), and erosion compared with TSL and farming income obtained by farmers (Table 8) which showed that mixed farms with classes I, II, and VI and dry field/rice field with class III, the land unit of column 2 gave erosion < TSL (column 6) with income (column 7)>SLN (Rp 32,000,000$ha^{-1}yr^{-1}$per household), the use of appropriate land, and decent income (column 8). This is due to the land use of mixed farms was dominated by cocoa crops followed by rambutan plants and other plants such as banana, corn and sweet orange with regular planting pattern by ex-transmigrants from Ladongi of Java and South Sulawesi origin who had experienced in planting cocoa. Meanwhile, the use of mixed farms in other units of the land was carried out by local people with irregular cropping pattern and without using the technology of fertilization and soil and water conservation.

In class III, mixed farm, the land unit of column 2 provided erosion < TSL, but the income was <SLN (Rp 32,000,000 $ha^{-1}$ $yr^{-1}$perhousehold) in column 7, and the land use was suitable but the income was not feasible (column 8).

The income result analysis of scenario 5 in selected land use in mixed farms. Furthermore, land of mixed farms of classes VI, and VIII, the land unit of column 2 gave erosion <TSL;the income was <SLN, so the land use was suitable but the income was not feasible (column 8). In classes VI, and VIII, the land unit ($36_{a-d,}$ $70_a$) in column 2 gave erosion>TSL in column 6 with income >SLN column 7, which was contrary to land unit $46_{a-b}$. The use of dry land in classes III, VI was not in accordance with the land ability and agro-technology with erosion>TSL and income <SLN (Rp 32,000,000 $ha^{-1}yr^{-1}$ per household).

**Table 8. Evaluation of land capability and suitability for agro-technology in 2015 in the Wanggu watershed**

| Class KL. | Land Unit | LU | (tons/ha/yr) Erosion | TSL | Erosionvs TSL | Income (Rp$ha^{-1}yr^{-1}$ per Household) x $10^6$ | Suitability and Feasibility Agrotechnology |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| I, II | $56_a$ , $76_{a-c}$, $78_{a-b}$ | Kc | 3.7-7.1 | 17.1-18.6 | < | 33.83 – 36.47 | Suitable/ feasible |
| III | $12_{a-e}$,$17_{a-f}$,$61_{a-d}$, | Kc | 3.7-5.5 | 17.6-18.1 | < | 19.75 – 31.23 | Suitable/not feasible |
| | $32_{a-b}$, $33_{a-f}$ | | 9.6-14.5 | 17.7-18.5 | < | 32.34 – 32.84 | Suitable/ feasible |
| | $19_{a-c}$,$50_{a-b}$,$71_{a-b}$ | Kc | 7.8-14.5 | 17.9-20.0 | < | 23.07 – 31.80 | Suitable/ not feasible |
| VI | $36_{a-d,}$ $70_a$ | | 12.5-28.4 | 10.6-18.1 | > | 32.75 – 32.06 | Not suitable/ feasible |
| | $46_{a-b}$ | | 12.5-29.1 | 10.6-18.1 | > | 26.69 | Not suitable/ not feasible |
| VIII | $28_{a-b}$,$34_{a-p}$,$47_{a-b}$ | Kc | 9.8-16.4 | 14.4-18.8 | < | 18.81 – 19.48 | Suitable/ not feasible |
| | $26_{a-d}$ | | 26.0 | 19.6 | > | 18.90 | Not suitable./ not feasible |
| III | $58_{a-b}$ | T | 7.1 | 17.3 | < | 32.02 | Suitable/ feasible |
| III,VI | $53_a$, $57_{a-e}$ | T | 24.3-36.5 | 18.5-18.8 | > | 18.74 – 12.25 | Not suitable/ not feasible |

**Note:** KL = land capability, LU= land use,TSL = tolerable soil loss,Kc = mixed farm, T = dry field

**Analysis of Farming Income as a result of Selected Land Use Scenario**

Kc1, Kc2, Kc3),dry land (T), and the change from dry land to mixed farm (Kc *) indicated that the erosion was< TSL with income >SLN, Rp 32,000,000 $ha^{-1}yr^{-1}$ per household (Table 9).This is to show that the change in selected land use with the application of agro-technology in the form of improved cropping pattern and Agrosilvopastoral has indicated the land use in line with its capability and feasible agro-technology with erosion < TSL and income > SLN. This is in line with what is stated by Sinukaban (2007), Marwah (2009), and Mayrowani and Ashari (2011) that the use of land which is suitable for land capability, agro-technology, and socio-economic farmer community can have a positive impact on increased agricultural productivity, income and sustainability of land resources due to the creation of farming sustainability through improved variety, agriculture, agronomy, feed and cattle.

**Table 9: Income analysis as a result of scenario-4: the use of selected land in the Wanggu watershed in 2015**

| KL. | Land Unit | LU | (ton/ha/yr) Erosion | TSL | Erosion vs TSL | Income(Rp $ha^{-1}yr^{-1}$ per Household) x$10^6$ | Suitability and Feasibility. Agrotechnology |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| III | $12_{a-e}$, $17_{a-f}$, $61_{a-d}$ | Kc1 | 3.5-5.5 | 17.6-18.1 | < | 34.15 – 35.31 | Suitable/Feasible |
| VI | $19_{a-e}$, $46_{a-b}$, $70_a$ | Kc2 | 7.8-12.2 | 10.6-17.9 | < | 34.06 – 35.73 | Suitable/Feasible |
| | $36_{a-d}$, $50_{a-b}$, $71_{a-b}$ | Kc3 | 3.7-12.9 | 18.1-20.0 | < | 32.75 – 34.29 | Suitable/Feasible |
| III | $57_{a-b}$ | T | 14.3 | 18.5 | < | 34.76 | Suitable/Feasible |
| VI | 53a | Kc* | 14.5 | 18.8 | < | 32.34 | Suitable/Feasible |

**Source:** Primary data obtained from the interpretation result of image map in 2014

**Note:** KL = land capability, LU= land use,TSL = Tolerable Soil Loss, Kc = mixed farm, T = dry field

## *Conclusion and Suggestion*

### Conclusion

1. Changes in land use in the Wanggu watershed in the period 1992 - 2013 have led to a decrease of forests by -25.3 % and shrubs -19.8 %, and an increase in mixed farms, dry fields/ rice fields and settlements, respectively +25.8%, 9.7%, and 9.4% of the watershed area, increasing the erosion effected by 0.74 tons/ha/yr (4.8%), RO 25.8 mm/yr (3.5%), CRO 0.02 mm $yr^{-1}$ (4.2%) and $Q_{max}$ / $Q_{min}$ 0.6 $yr^{-1}$ (2.6%).

2. Forestlands have physical characteristics such as low weight volume, porosity, organic material, field capacity, soil infiltration capacity, the percentage of land cover, potential interception and high surface roughness which had a very significant role in lowering surface runoff, fluctuations in discharge rate (Qmax, Qmin, KRS), erosion and sedimentation, which was contrary to the land use of mixed farms, dry land / rice fields, shrubs and settlement.

3. The model of land use in the Wanggu watershed in the period 1992-2015 which was generally applied to farmers was not in line with land capability and agro-technology which had an impact of reducing infiltration capacitance and increasing runoff, the coefficient of river regime, erosion >TSL, and farmers' income of Rp 32,000,000 $ha^{-1}yr^{-1}$ per household had not been sufficient for a decent life, except for such land units as$32_a$, $33_{a-b}$, $56_a$, $58_{a-b}$, $76_{a-c}$ and $78_{a-b}$.

4. The model of land use planning and agro-technology of scenario4 (34.0% forest, 15.2% settlement, 39.8% mixed farm + *Agrosivopastoral - prenual crops* (cocoa, citrus, teak, bananas, grass + 3 head of cattle) and 11.0% dry land (rice field + cropping pattern Jg + Kd + Cb) was the most appropriate in the management of sustainable watershed because it had been able to produce runoff, discharge coefficient, river regime coefficient ($Q_{max}$ /$Q_{min}$42.3 to 18.5< 30) and lower erosion 35.6 tons$ha^{-1}yr^{-1}$ to 10.1 tons $ha^{-1}yr^{-1}$< TSL 12.1 tons $ha^{-1}yr^{-1}$, and to increase the income of farmers amounting to Rp 32,340,000 $ha^{-1}yr^{-1}$ per household until Rp 35,730,000 $ha^{-1}yr^{-1}$ per household.

### *Suggestion*

1. The use of mixed farm / agroforestry (cocoa, citrus, pepper, banana, elephant grass) where corn is inserted between the main crop for 3 growing seasons in land units $32_a$, $33_{a-b}$, $56_a$, $58_{a-b}$, $76_{a-c}$ and $78_{a-b}$ needs to be continuously done because it has been able to conserve land resources with income exceeding the needs of decent living, Rp 32,000,000 household / year).

2. The planning model of land use and agrotechnology as a simulation result of Scenario-4 (34.0% forest, 15.2% settlement, 39.8% mixed farm + *Agrosilvopastoral-perennial crops (*cocoa, citrus, teak, bananas, grass + 3 head of cattle) *and* 11.0% dry land + *improvement of the cropping patterncorn + soyben + pepper*is the most appropriate in the management sustainable watershed, so that it needs to be implemented and followed up for the improvement of spatial planning, both by the provincial government of Southeast Sulawesi and the central government.

## *References*

Alwi L., N. Sinukaban, S. Solahuddin, dan H. Pawitan, 2011. Study of land use change impacts on land degradation and hydrology condition of Wanggu watershed. Journal of Science Agriplus Vol. 21 No. 03p.214 – 223, Kendari September 2011, ISSN 0854 – 0128.

Alwi L., N. Sinukaban, S. Solahuddin, dan H. Pawitan, 2011. Study of land use dynamic impact on erosion and hydrology condition of Wanggu watershed. Journal hidrolitan, vol. 2 No. 2, ISSN: 2086-4825. Community of soil and water conservation of Indonesia (CSWC), Branch of Jambi.

Alwi L. dan S. Marwah, 2014. Land use impacts on water resources. Agrotechnos journal, vol. 4 No. 2, Kendari July 2014. ISSN: 2087-7706.

Anas I., Gulton T and Migge S. 2005.Soil Microbial Population and Activity at Different Land Use Type. In: Stictentroth D, W. Lorenz, S.D. Tarigan, A. Malik (eds). Proceedings International Symposium "*The Stability of Tropical Rainforest Margins: Linking Ecological, Economic and Social Constrain of Land Use and Conservation*" 19-23 September 2005. Geor-August-University of Goettingen, Germany: Universitatsverlag Goettingen: 162.

Arsyad, S., 2010. Water and soil conservation, Faculty of Agriculture IPB. PT. IPB Press, Second Edition. Campus of Taman Kencana, Bogor.Asdak, C., 2007. Hidrologi dan Pengelolaan Daerah Sungai, Gadjah Mada University Press, Bandung.

Black, P.E., 1996. Watershed Hydrology. State University of New York. College of Environmental Science and Forestry Syracuse, New York.

[BPDAS] Balai Pengelolaan Daerah Aliran Sungai Sampara, 2008. *Pola Rehabilitasi Lahan dan Konservasi Tanah DAS Sampara*, Kendari.

Chang, M., 2002. Forest Hydrology, An Introduction to Water and Forest. CRC Press, Boca Raton, London, New York, Washington, D.C.

Handayani, Y.H., Jayadi, dan B. Triatmojo, 2005. Optimazing of land use system and Technic design implementation in flood analysis of waterhsed: Case study upstrem Ciliwung watershed in Bandung Katulampa. Journal human and environment, vol.12 No. 2 PPLH UGM, Jogyakarta.

Iswandi, M. R., 2003. Analysis of Kendari Bay Sedimentation Impact on the community activities and its prevention strategies. Dissertation of postdoctoral program, Bogor Agriculture University.

Lihawa F., 2009. The Efect of Watershed Environmental Conditions and Land Use on Sediment Yield in Alo-Pohu Watershed.Indonesian Journal of Geography. The Faculty of Geography, Gadjah Mada University Yogyakarta Indonesia & the Indonesian Geographers Association. Indo J.Geog, Vol 41, No.2, page 103 – 203, Yogyakarta Desember 2009, ISSN 0024 9521

La Baco, 2012. Analysis of land use alternative to guarantee available water resources in Konaweha watershed Southeast Sulawesi Province. Postdoctoral school, Bogor Agriculture University.

Marwah S., 2000. *Perencanaan Sistem Usahatani Lahan Kering Dalam Rangka Mewujudkan Pertanian Berkelanjutan di DAS Wanggu Kendari, Sulawesi Tenggara*. Thesis. Graduate master program. Bogor Agricultural University.

Marwah S., 2008. Optimation of agroforestry system management for sustainable agriculture development in Konaweha watershed South East Sulawesi, Postdoctoral school. Bogor Agricultural University.

Marwah S., 2009. Analysis of economy farming of agro forestry system for decent standard life needs of farmer in Konaweha watershed South East Sulawesi. Journal Science of Agriculture, Gakuryoku, Vol. XV, No.1, pages 14-19, PERSADA Bogor, April 2009, ISSN 0853-7674.

Marwah S and L. Alwi, 2014.Analysis of the Impact of Land Use Change on Tidal Flood in Kendari City. International Journal of Applied Science and Technology. Vol. 4, No. 7 December 2014, Center for Promaoting Ideas, New York, USA.ISNN 2221-0997 (Print), ISSN 2221-1004 (Online).

Marwah S., 2012. Physical Feasibility Study of Agro forestry Farm System to Support Sustainable Agriculture in Konaweha Sub Watershed of Southeast Sulawesi. Journal of Tropical Soil, Vol. 17, No.3.Lampung September 2012. ISSN 0852-257X

Mayrowani, H., dan Ashari (2011).Agro forestry Development to support the Food Security and Farmer Empowerment Neighborhood Forest. Agro-Economic Research Forum, FAE, Vol. 29 No. 2, P.83-98, Bogor in December 2011, ISSN. 0216-4361.

Sajogyo, 1977. Poverty and Minimum Need Food. Rural Sociological Research Institute (LPSP). IPB, Bogor.

Sinukaban, N., 2007. The rule of soil and water conservation in watershed management in Bunga rampai soil and water conservation. The center association of community soil and water conservation Indonesia. Jakarta, pages: 35-44.

Sinukaban, N., 2008. The rule of soil and conservation in flood mitigation. Proceeding Seminar of Soil and water conservation. Association of watershed of Lampung Provinsi. Bandar Lampung, Indonnesia

Act No. 26 of 2007 on Spatial Planning, Association Regulation Legislation, Publisher FM Fokusmedia, Bandung.