Current Watershed Functioning of Manupali

This series is created to help stakeholders inform the design of rewards for environmental services (RES) mechanism in Manupali watershed. In this issue, we highlight the results of the GenRiver model, as part of the Rapid Hydrological Appraisal (RHA) conducted for Manupali watershed, from July 2009 to January 2010.

Basic Facts about Lantapan

- 70% of Manupali watershed lies within the Municipality of Lantapan, Bukidnon province
- 71% of Lantapan's area (35, 465 ha) has slopes greater than 18%
- Elevation range is 320-2,938 masl
- Type IV climate with evenly distributed rainfall with indistinct dry and wet seasons
- Maximum annual rainfall is 2,522 mm (1994-2005)
- Well-drained soils with clayey surface and subsoil horizons; slightly to moderately acidic with low organic matter and high Phosphorous fixation capacity; low capacity to retain nutrients
- Major crops grown: corn, sugarcane, rice, coffee, temperate vegetables, pineapples and bananas
- 60,000 people totally depend on surface water for irrigation and domestic purposes
- Downstream, hundreds of thousands of people and industries depend on Manupali's water for rice irrigation and hydropower generation
- Competition arise among downstream users during peak dry months due to low flows and poor water quality
- Causes of water scarcity: forest degradation, land use conversion, water abstraction, and unsustainable farming practices
- Efforts to protect and sustain watershed services are hampered by lack of understanding on watershed functions, and insufficient data to recognize the impacts of land use, land use change and forestry (LULUCF) on such functions.

GenRiver Model

The GenRiver model is a simple hydrological tool developed by the World Agroforestry Centre (ICRAF) in Bogor, Indonesia to assess how LULUCF can affect watershed functions. It accounts rainfall (P) and traces the subsequent flows and storage in the watershed, which can lead to either evapotranspiration (E), river flow (0) or change in storage (ΔS).

The GenRiver was applied in three hotspot sub-watersheds: Alanib (ASW), Kulasihan (KSW) and Maagnao (MSW). Tree cover and agroforestry land use are decreasing while crop cultivation continues to expand (Table 1). In the absence of daily riverflow, the 22% runoff coefficient was used, which exemplifies many of Philippine watersheds.

Table 1- Comparative land cover changes of Alanib and Kulasihan sub-watersheds within Manupali watershed in 1990, 2002 and 2007.

	Area (ha)						1990-2002				2002-2007			
	Alanib SW			*Kulasihan SW*			*Alanib SW*		*Kulasihan SW*		*Alanib SW*		*Kulasihan SW*	
Land use	*1990*	*2002*	*2007*	*1990*	*2002*	*2007*	*Change*	*%*	*Change*	*%*	*Change*	*%*	*Change*	*%*
Agriculture mix	841.5	1033.5	1502.1	1493.9	1560.6	2597.7	0.2	18.6	0.0	4.3	0.3	31.2	0.4	39.9
Agroforestry	2256.1	2050.0	1441.4	3840.6	4090.0	2297.5	-0.1	-10.1	0.1	6.1	-0.4	-42.2	-0.8	-78.0
Banana	25.8	62.6	20.1	122.1	387.6	190.9	0.6	58.8	0.7	68.5	-2.1	-212.1	-1.0	-103.1
Cleared land	22.1	1.0	0.8	62.5	26.3	6.3	-21.4	-2136.4	-1.4	-137.7	-0.2	-22.2	-3.2	-317.1
Cloud/Shadow/ Water body	113.0	36.8	89.2	812.0	0	402.8	-2.1	-207.1		0.0	0.6	58.7	1.0	100.0
Corn/sugarcane	101.9	195.3	252	240.7	361.9	770.0	0.5	47.8	0.3	33.5	0.2	22.5	0.5	53.0
Forest	2898.5	2733.2	2664.5	2596.2	2504.3	2454.5	-0.1	-6.0	-0.0	-3.7	-0.0	-2.6	-0.0	-2.0
Pineapple	0	2.4	8.3	0	2.3	40.0	1.0	100.0	1.0	100.0	0.7	70.7	0.9	94.4
Ricefield	17.7	56.3	83.2	254.3	309.4	401.4	0.7	68.5	0.2	17.8	0.3	32.2	0.2	22.9
Settlement	12.4	14.9	20.7	14.5	96.6	123.9	0.2	16.4	0.9	85.0	0.3	28.3	0.2	22.1
Shrubland	292.1	395.2	499.1	260.6	358.5	412.3	0.3	26.1	0.3	27.3	0.2	20.8	0.1	13.1
Total	6581.3	6581.3	6581.3	9697.3	9697.3	9697.3								

Source: ICRAF-ASB

Model Performance

- The model was simulated with rainfall data from 1 January 1994 to 31 December 2005.
- Using the Nash-Sutchliffe Efficiency (NSE), the model performance in ASW was generally good (NSE 0.88-1.00). The bias was less than 35%, with coefficient of correlation (r) ranging from -1.00-1.00.
- In KSW, the model performance was also good (NSE 0.53-1.00) with coefficient of correlation (r) at -1.00-1.00 and with less than 45% bias.
- The model has thus captured 75% and 58% of observed patterns across the 12-year period in ASW and KSW, respectively.

River Discharge

- Recharge of soil and water occurred in most of the 12-year hydrological periods in ASW (Fig 1). The 1994 cumulative discharge showed a direct (straight) relationship between computed and simulated values per unit rainfall (NSE=0.81). However, the 1999 simulation was unsatisfactory (NSE=0.32), with higher values beyond 500 mm compared to the computed discharge values. Furthermore, the 2003 simulation indicated sensitivity to climate change (NSE=1.00), resulting in imbalance between demand and supply of water during dry months. It also indicated flash floods towards the end of the year, where the absorptive capacity of soil was at its peak and ASW's buffering capacity was low.
- In KSW, a straight correlation was recorded in 1994. The simulated river flow from 1994-1997 was very low at 25 mm day^{-1}. Extremely high simulated peak flows occurred in 1998-1999, which exceeded KSW's storage capacity, indicating overflow or flooding. The local ecological knowledge-public ecological knowledge (LEK-PEK) results revealed that land conversion and preparation for banana plantations commenced at this time, exposing barren lands to rainfall, thereby increasing soil runoff in KSW.

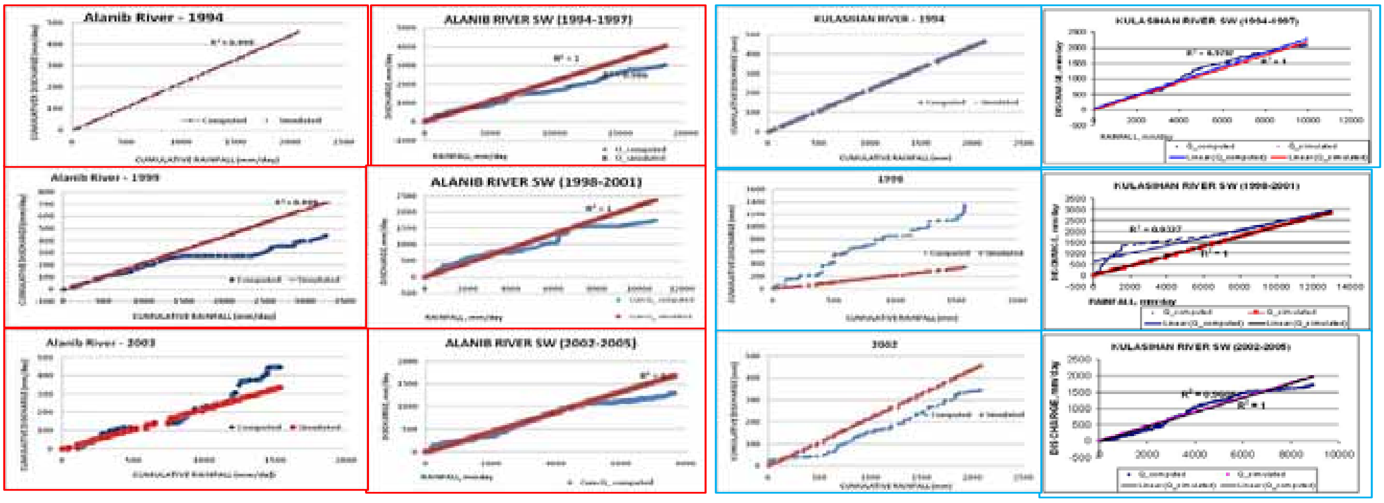

Fig. 1- Annual cumulative river per unit rainfall water in Alanib and Kulasihan sub-watersheds.

Water Balance

- The annual water loss through evapotranspiration in KSW was 12% higher than in ASW (Table 2). Agriculture-based land use is greater in KSW, which makes the ground surface more exposed to rainfall events. Extensive cultivation of short rotation cycle crops also contributes to artificial water loss through frequent harvesting.
- Riverflow in KSW was higher by 6% in ASW, although runoff rate was the same. Surface quickflow was slightly higher in KSW.
- Baseflow in KSW was zero, indicating low water storage capacity and insufficient groundwater recharge. With clayey soil, the riverbed easily dries up in the dry season. This explains the unstable discharge rates in Kulasihan River, which is highly influenced by rainfall. Water level directly rises even with moderate rainfall, while flooding occurs with heavy rainfall.

Table 2- Water balance of current, increase agriculture cover scenario (2), and increase shrub lands through fallow scenario (3) in Alanib and Kulasihan sub-watersheds during 12-year simulation (1994-2005)

No	Dynamics of water	Alanib sub-watershed				Kulasihan sub-watershed			
		Observed	*Simulated*			*Observed*	*Simulated*		
			Current	Scenario 2	Scenario 3		Current	Scenario 2	Scenario 3
1	Precipitation (mm)	2272.36	2272.36	2272.36	2272.36	2300.67	2300.67	2300.67	2300.67
2	Evapotranspiration (mm)		760.42 (33.54)	1064.58 (46.85)	1703.33 (74.96)		1058.50 (46.01)	438 (19.04)	620.5 (26.97)
3	Other Losses		667.58 (29.37)	382.12 (16.82)	71.9 (3.16)		261.82 (11.38)	599.73 (26.07)	1180.08 (51.29)
4	Riverflow		844.98 (37.18)	825.66 (36.34)	497.13 (21.88)		980.35 (42.62)	1262.94 (54.89)	500.09 (21.73)
	-Runoff (mm)	496.12	516.49 (22.72)	497.17 (21.88)	497.13 (21.88)	535.2	536.90 (23)	546.60 (23.78)	488.44 (21.23)
	-Soil Quick Flow (mm)		≥0.00	0	0		31.00 (1.35)	182.5 (7.93)	8 (0.35)
	-Surface Quick Flow (mm)		-	-	-		412.45 (17.92)	412.45 (17.92)	3.65 (0.16)
	-Baseflow (mm)		328.49 (14.45)	328.49 (14.45)	0		0	121.39 (5.47)	3.65 (0.16)

*Value in parentheses is in percentage

Indicators of Watershed Function

Watershed functions were assessed using water transmission (total water yield per unit rainfall), buffering capacity (relationship of peak river flow and peak rainfall, linked to flooding risk), and gradual release of groundwater during dry season (based on recharge in the rainy season) as key indicators (Table 3).

- In ASW, water transmission was erratic. The gradual water release indicator (baseflow fraction) was slightly declining. Although the total discharge fraction and buffering indicator did not significantly vary over time, degradation pattern was observed from 2000 where the relative buffering indicator started to drop, coinciding the establishment of banana plantations. Nonetheless, buffering peak event was higher than water transmission, indicating its capacity to buffer high rainfall events, thus minimizing flood occurrence.
- In KSW, water transmission did not change significantly. The gradual water release fraction, particularly soil quickflow, slightly increased through time (R^2=0.67), which was the same for the highest monthly discharge fraction (R^2=0.12). There were no changes in the buffering peak event. However, the relative buffering indicator slightly decreased over the 12-year simulation, indicating the degradation pattern of KSW. With an already fragile ecosystem, decreasing tree cover may further reduce its already declining buffering capacity functions, thereby increasing the risk of landslides in sloping areas and flooding downstream.

Three scenarios were simulated to determine the effect of LULUCF on discharge, water balance and watershed functions: (1) current, (2) increased agricultural mix and decreased forest and agroforestry by 30%, and (3) increased shrubland through fallow (Table 2).

- In ASW, scenario 3 produced higher riverflow and highest evapotranspiration rate, with slightly lower soil runoff. However, it recorded a zero baseflow, implying a decreased capacity to store water. Scenarios 2 and 3 were 32 and 18% higher in water yield compared to current scenario.
- In KSW, scenario 2 produced higher monthly river discharge, and the least evapotranspiration rate, but with slightly higher soil runoff at 25% of the riverflow. Baseflow was 5%, while current and scenario 3 had zero.
- Overall, scenario 2 presents decreasing buffering capacity for both ASW and KSW.

Table 3- Average of indicators of Alanib and Kulasihan sub-watershed functions (1994-2005)

Indicators	Alanib sub-watershed						Kulasihan sub-watershed					
	Observed			*Simulated*			*Observed*			*Simulated*		
	Min	*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*	*Ave*	*Max*
Total discharge fraction	0.22	0.22	0.22	0.22	0.24	0.31	0.22	0.22	0.22	0.22	0.22	0.22
Buffering indicator	0.77	0.78	0.79	1.00	1.00	1.00	-	0.998	-	0.78	0.78	0.78
Relative buffering indicator	-1.08	-0.04	0.50	0.73	0.93	0.97	-	-	-	-0.24	-0.01	0.21
Buffering peak event	0.56	0.76	0.92	0.73	0.93	1.00	-	0.998	-	0.78	0.78	0.78
Highest month fraction relative to mean rainfall	0.37	0.51	0.66	0.23	0.44	0.65	-	-	-	0.32	0.40	0.50
Lowest month fraction relative to mean rainfall	0.01	0.06	0.14	0.004	0.06	0.12	-	-	-	0.01	0.07	0.17
Surface quick flow	-	-	-	0	0	0	-	-	-	0.01	0.11	0.79
Soil quick flow fraction	-	-	-	0	0	0	-	-	-	0	0.01	0.12
Baseflow fraction	-	-	-	0	0.35	7.87	-	-	-	0	0	0

Implication to Rewards for Watershed Services (RWS)

The results of the GenRiver model are not conclusive in the absence of actual daily discharge, however these provided a clearer picture on the current hydrological behavior of the Manupali watershed. Indeed, LULUCF of ASW and KSW, coupled with increasing water demand have significantly altered river discharge patterns, water balance and watershed functions.

The following actions are suggested:

- Rehabilitation of degraded riparian zones through planting appropriate tree species and bamboos to buffer the unpredictable peak flows and flooding, minimize landslides along stream banks and river bed sedimentation.
- Investment in gauging stations and instrumentation in major rivers to generate useful data (i.e., daily river discharge) by the Department of Environment and Natural Resources (DENR) and Local Government.
- Repair and maintenance of Automatic Weather Stations (AWS) in Lantapan to generate rainfall data and other climatic parameters necessary in predicting riverflows and water balance.

By combining multiple knowledge systems generated through LEK-PEK surveys and the modeling work of scientists (MEK), the following actions are recommended:

- develop land-use policies and incentives that encourage sustainable land use;
- regulate water rights allocation;
- effectively coordinate water management institutions; and
- foster watershed-level collective action for co-investment and equitable benefit-sharing.

This requires recognition and respect for upstream communities and their capacity to protect and maintain watershed services through ES-friendly land use practices. Therefore, a combination of public and private rewards can be a way forward to sustain the functions of Manupali watershed.

What's next?

We will feature the RWS of National Power Corporation (NPC)-Pulangui IV to the agroforesters and tree farmers in Alanib sub-watershed of Manupali.

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