Supplement Feedback to comments by anonymous Referee of

"Infiltration-Friendly Land Uses for Climate Resilience on Volcanic Slopes in the Rejoso Watershed, East Java, Indonesia"

by Didik Suprayogo et al.

Supplement Note 1: The additional data to revise Table 2.

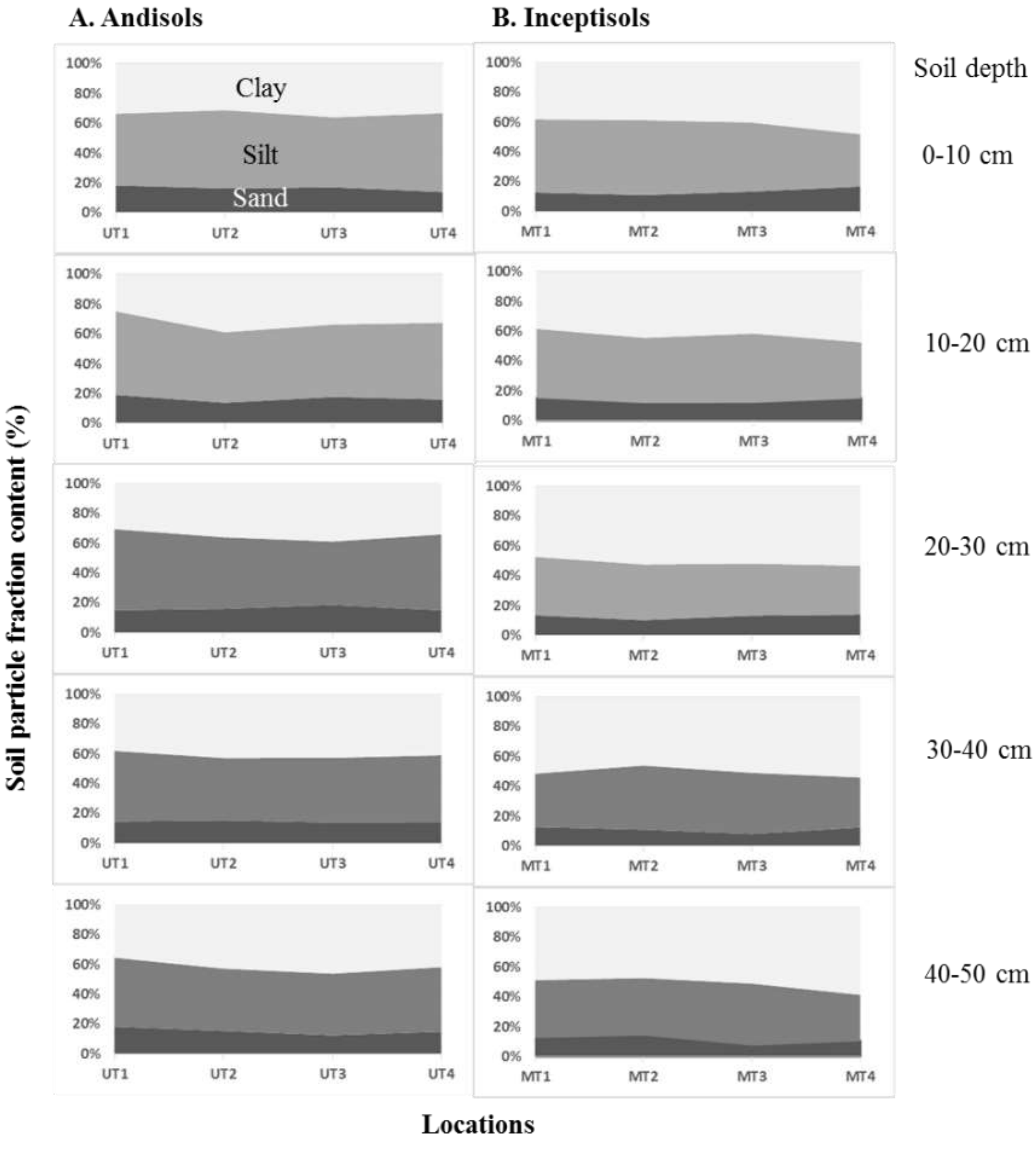

Figure 1. Soil texture in five different layers in runoff plot measurements

Table 2. bulk density, particle density, soil porosity, macro-porosity and organic C of runoff plots

a. Upstream Rejoso watershed: Andisols

Location code	Bulk Density (g cm^{-3})*			Particle Density (g cm^{-3})*			Soil porosity (%)*			Soil Macro-porosity (%)			C_{org} (%)*		
	At soil depth (cm)														
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
UT1	0.87a	0.81a	0.83a	2.16a	2.23a	2.31a	60a	63a	64c	8.0b	5.2b	0.9a	2.05bc	1.61c	1.79b
UT2	0.85a	0.86a	0.82a	2.27a	2.30a	2.33a	63a	63a	65c	5.1ab	1.5a	0.3a	2.46c	1.56bc	1.78b
UT3	0.81a	0.84a	0.85a	2.14a	2.12a	2.28a	62a	60a	63b	4.7ab	2.1ab	1.4a	1.17a	0.58a	0.71a
UT4	0.84a	0.88a	0.84a	2.28a	2.29a	2.08a	63a	62a	60a	3.0a	0.3a	0.1a	1.35ab	1.06ab	0.92a
LSD	0.07	0.13	0.12	0.17	0.21	0.38	4	5	1	3.52	3.4	1.8	0.85	0.50	0.50

b. Midstream Rejoso watershed: Inceptisols

Location code	Bulk Density (g cm^{-3})*			Particle Density (g cm^{-3})*			Soil porosity (%)*			Soil Macro-porosity (%)			C_{org} (%)*		
	At soil depth (cm)														
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
MT1	0.83a	0.85a	0.83a	2.20a	2.28a	2.20a	62c	63a	62b	13.6ab	7.0bc	2.5c	1.73a	1.87a	1.65b
MT2	0.96b	0.91a	0.91a	2.42b	2.38a	2.21a	60bc	62a	59ab	16.1b	8.3c	1.8bc	2.22a	1.59a	1.84b
MT3	1.03bc	0.96a	0.94ab	2.38b	2.36a	2.40a	57ab	59a	61b	11.7a	3.4ab	0.9ab	2.19a	1.61a	1.01a
MT4	1.09c	1.04a	1.04b	2.38b	2.33a	2.33a	54a	55a	55a	11.4a	0.8a	0 a	1.71a	1.36a	1.12a
LSD	0.10	0.24	0.11	0.15	0.17	0.22	4	10	4	4..0	3.9	1.0	0.84	0.54	0.41

*The same letter indicates no statistically significant differences between location with Fisher's LSD test ($p<0.05$).

Note: soil macro porosity measured using metyline blue method, will be describe in the Material and Method

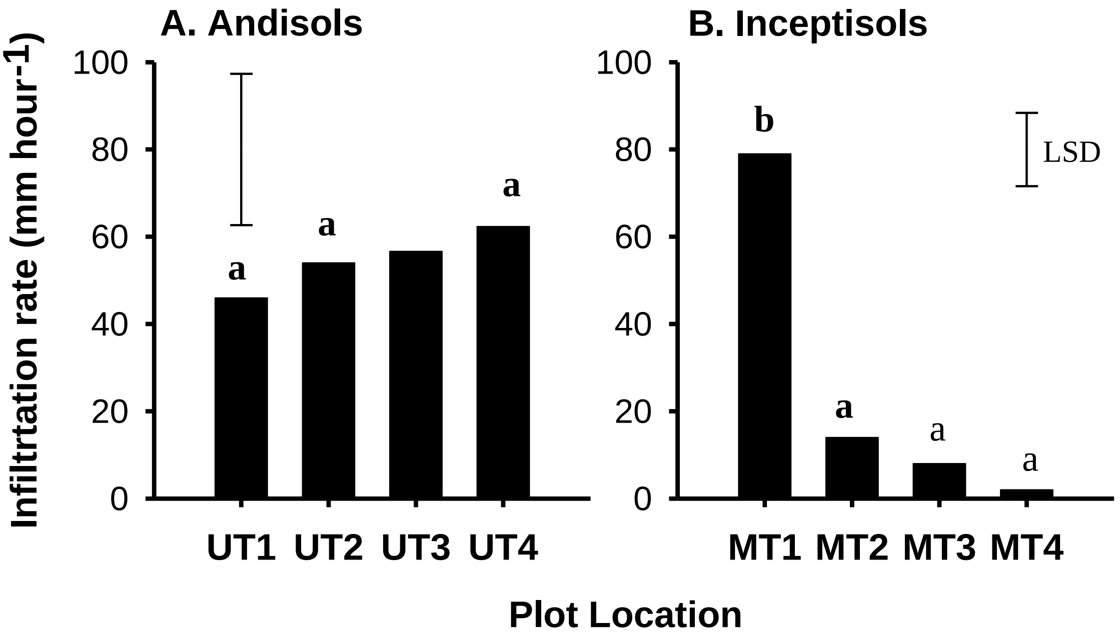

Figure 2. Soil Infiltration rate measured using double ring infiltrometer (n=6)

Supplement Note 2

Table : The depth factor of some soils in Indonesia (Hammer, 1981)

Soil taxonomy	Soil degradation		Factor of soil depth
Sub order	Physical	Chemical	
Aqualf (AQ)	M	L	0.90
Udalf (AD)	M	L	0.90
Andept (IN)	L	L	1.00
Aquept (IQ)	L	M	0.95
Tropept (IT)	L	L	1.00
Udult (UD)	M	M	0.80

Supplement Note 3

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Supplement Note 4. Through-fall /Rainfall ratio variability

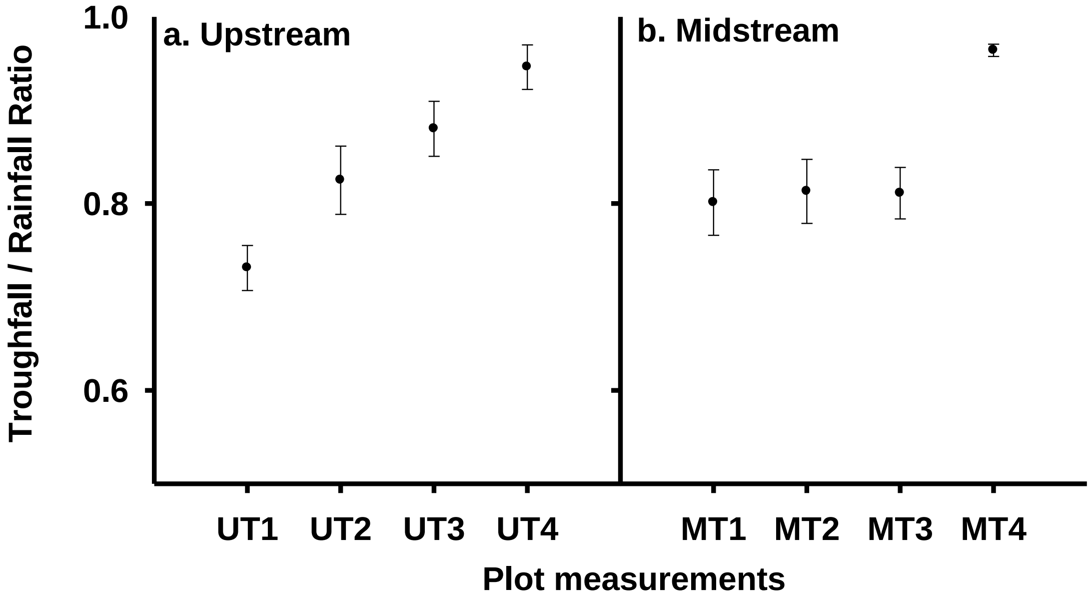

Figure.. The Through-fall /Rainfall ratio variability in measured runoff plot, Rejoso Watershed

Supplement Note 5. Filtering sediment using old newspapers

Supplement Note 5.

4 Discussion

The first research question with hypothesis that forest-to-open-field-agriculture continuum significantly decreases the soil hydrological function of forest. The results of the present study confirms that land use type from high density of trees in forest were significantly decreased soil infiltration rate compared with low density of trees in agroforestry (Table . 2). The results of this study are also supported from the results of previous studies, where found that decreases in ground cover often resulted in decreases in soil infiltration rate (Gifford and Hawkins, 1978, Suprayogo et al., 2004, Forests have been shown to reduce surface runoff and erosion compared with coffee monoculture (Widianto et al., 2004). Neris et al. (2012) also found that soil infiltration in both green forest and pine forest higher than cropland. Ma et al. (2007) who found that soil infiltration rate of forest was greater than that of agroforestry. Sun et al., (2018) reported from their meta-analysis that converting any land use type with vegetation cover to crop land is in favour of decline of soil infiltration rate and are not beneficial to soil and water conservation. However, Wang et al. (2015) reported that conversion from forest to agroforestry increased soil infiltration rate.

The degradation of soil hydrological function of forest could be attributed to the decrease of soils' macroporosity and organic matter content, increased soil bulk density (Fig…..) which had significantly positive correlation with soil initial and steady infiltration rates (Fig. ….). Among various land use patterns, plant root activities are important factors affecting soil infiltration (Butt and Bowman, 2002; Zimmermann et al., 2006). The reason why cropland has lower infiltration rate than The and use type from high density of trees compared with low density of trees in forest may be verified by the fact that soils beneath the canopies of woody plants had a more extensive distribution of plant roots and a greater number of macropores, biologically-produced pores (Dunkerley, 2000; Colloff et al., 2010), which created a positive feedback on infiltration (Reid et al., 1999; Bhark and Small, 2003). The soils' macroporosity, needed for effective infiltration, is the result of a continuous process of compaction and filling in of macropores with fine soil particles, and creation of biogenic channels (formed by old tree roots, earthworms and other soil engineers) or abiotic processes (cracks). As no heavy machinery is used in any of these land use systems, compaction is restricted to human feet, and motorbikes in specific tracks. The formation of old tree root channels can cause long time-lags between land cover change and soil macroporosity (van Noordwijk et al. 2011), obscuring relations between current tree cover and soil hydrologic functions. Zwartendijk et al. (2017) showed that 'fallows' were intermediate between forests and grasslands in terms of infiltration in Madagascar. Recovery of infiltration after reforestation of grasslands in the Philippines was found to be a matter of decades rather than years (Zhang et al. 2019). Suprayogo et al. (2004) proves that forest soils have relatively more pore macro and higher surface infiltration rates than monoculture coffee plantations. Land use change, especially from forest to cropland, have caused remarkable changes in soil properties including loss of organic matter and increases in bulk density (Lepsch et al., 2010), which lead to decrease infiltration rate (Mwendera and Saleem, 2010). Some researchers suggested a positive relationship between soil organic matter and infiltration rate (Martens and Frankenberger, 1992; Osuji et al., 2010).

The second research question come out with hypothesis that dominant factors that determine "infiltration friendly" on plot scale are tree canopy cover, understorey vegetation, litter necromass, and land surface roughness. Our research show that a number of land cover types had infiltration rates below the required rates at peak rainfall events. Among the four factors tested, tree cover and litter layer necromass could be used to define zone-specific thresholds for infiltration-friendly land use, but understory vegetation and surface roughness did not. Although slopes in the upper watershed are much steeper than midstream, the coarser texture and likely higher aggregate stability means that thresholds for canopy cover and litter necromass can be lower.

Many authors have emphasized that the key to hydrologic functions is in the soil rather than the aboveground parts of the forest (Peña-Arancibia et al. 2019). Still, we found strong and direct relations with canopy cover. Positive effects of canopy cover on infiltration were related to raindrop interception in earlier studies (Carlesso et al. 2011; de Almeida et al. 2018). Interception will (a) reduce the destructive power of rainwater splash on the ground surface (as long as the effects Wiersum (1974) described are avoided, (b) allow more time for infiltration as water reaches the surface more slowly, (c) keep a thin water film on the leaves that will (d) cool the surrounding air when it subsequently evaporates. It will reduce the amount of water reaching the soil surface, but by increasing air humidity also decrease transpiration demand when stomata are open.

Understory vegetation theoretically can reduces splash impacts on the soil and supports infiltration, as does the litter necromass present. However, the result of this study indicated that understory show no significant relationships with runoff coefficient and soil erosion. This is possible because surface runoff and erosion have been largely controlled by land cover. Growth and development of understory determined by canopy cover. Likewise, the tree plantations in each plot are also diverse, so this also affects the diversity of understorey vegetation underneath.

The litter function is provided by thick litter closure at the ground surface. The result of this study indicate that litter layer in the old production forest both in upstream and midstream is significantly higher that other land uses (Table 3) and there is significant correlation with runoff coefficient and soil erosion (Figure 6 and Figure 7 respectively) . Litter is part of the body of the plant (in the form of leaves, branches, twigs, flowers and fruit) that dies (deciduous or pruned) and lives on the surface of the soil either intact or partially weathered. The role of litter in maintaining infiltration and soil erosion through: (a) Maintaining soil looseness by protecting the soil surface from rainwater, so that aggregates and soil macro pores are maintained, (b) Providing food sources for soil organisms, especially 'soil diggers' (eg earthworms)), so that the organism can live and develop in the soil. Thus the number of macro pores is maintained through the activity of these organisms, and (c) Maintaining water quality in the river through the filtering of soil particles carried by surface runoff before entering the river. In a study in North China, Li et al. (2014) showed that presence of litter of *Quercus variabilis*, representing broadleaf litter, and *Pinus tabulaeformis*, representing needle leaf litter, can reduce surface runoff rates by 29.5% and 31.3% respectively. The overall effect of fast plus slowly decomposing surface litter means protection of the soil surface from splash erosion, surface roughness that reduces sediment entrainment, an energy source for soil biota and a conducive microclimate (Hairiah et al. 2006, Derpsch et al., 2014).

The land surface roughness also determine to maintain high infiltration and reducing soil erosion. In upstream there is no significant different between land uses, but in midstream, land surface roughness in agroforestry systems with tightly different canopies is significantly higher than rare canopies (Table 3). Without a high canopy cover (Table 3.a), this roughness was not able to control surface runoff and erosion in the upstream area. This is due steep slope in this plot. Both the production forest and agroforestry systems with high canopy maintained a relatively high land surface roughness compared with rare canopies in midstream area..In midstream, the land surface roughness were significant correlations with runoff coefficient and soil erosion. The role of surface roughness as sediment filter may depend on frequent regeneration to counter homogenisation (Rodenburg et al. 2003). Surface roughness in the landscape includes a cavity, meandering of streams due to the present of litter, necromass, tree trunk and rocks, providing opportunities for water flow to stop for longer periods and experience infiltration. This condition also functions as a sediment filter. This function needs to be managed through land management, so that surface roughness is maintained on the ground.

The third research question is as an analysis the answers of the previous two research questions with the hypothesis that it is not always that the upstream watershed area is more sensitive to hydrological disturbance due to changes in land use than midstream, but the factor of soil properties also determines considerations in watershed hydrological management. From a land use policy perspective our results suggest that maintaining high (~80%) canopy cover in the mid-slope farmer-controlled landscape that does not match the slope criteria for designation as watershed protection forest, is important. In Indonesia, protection is forest areas that have the primary function as protection of life support systems to regulate water management, prevent flooding, control soil erosion, prevent sea water intrusion, and maintain soil fertility (Government of Indonesia, 1999). With the higher rainfall intensities here and more erosive soils, risks for degradation from a downstream perspective seem to be as important here as they are in the more visually-at-risk upper watershed zone. Combining our plot-level results with efforts for hydrologic modelling for the Rejoso catchment as a whole (Tanika et al. 2018) can guide further advice to a local watershed forum on the measures and incentives needed to restore and protect the watershed as a whole. The Indonesian legal requirement of 30% forest cover across all its local government entities (Government of Indonesia, 2007) is a coarse translation of hydrologic relations at risk. It clearly matters what the land cover in the 'non-forest' parts of the landscape is and how vegetation interacts with soils and geomorphology in shaping rivers and groundwater flows (Zhipeng et al. 2018; Zhao et al. 2019). Our findings for the Rejoso watershed show that within the agroforestry spectrum, hydrologic thresholds of infiltration-friendliness exist between the systems that are mostly 'agro' and those that are mostly 'forest'.

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Supplement Note 6:

Table 3. Canopy cover, understory vegetation, litter necromass, and soil roughness of the sample plots

a. Upstream Rejoso watershed

Code	Land cover	Tree canopy cover (%)*	Understorey vegetation (t ha^{-1})*	Litter (t ha^{-1})*	Soil roughness (%)*
UT1	Old production forest	55 b	10.1 b	9.2 b	8.5 a
UT2	Young production forest	40 b	10.5 b	2.0 a	7.0 a
UT3	Agroforestry	4 a	10.1 b	2.1 a	9.5 a
UT4	Arable land	0 a	3.7 a	0.3 a	7.7 a
LSD		15	5.6	3.7	4.6

b. Midstream Rejoso watershed

Code	Land cover	Tree canopy cover (%)*	Understorey vegetation (t ha^{-1})*	Litter (t ha^{-1})*	Soil roughness (%)*
MT1	Old production forest	87 c	2.5 a	9.8 b	7.6 b
MT2	Agroforestry	75 c	2.5 a	4.8 a	5.4 ab
MT3	Agroforestry	52 b	2.1 a	5.2 a	2.8 a
MT4	Agroforestry	26 a	1.3 a	3.5 a	2.0 a
LSD		14	2.6	2.4	4.5

**The same letter indicates no statistically significant differences between location with Fisher's LSD test ($p<0.05$).*

Table 4. Rainfall, runoff, ratio runoff/rainfall and soil erosion in the runoff plots in each land cover type

a. Upstream Rejoso watershed

Code	Land cover	Ranfall (mm)	Runoff (mm)*	Runoff/ rainfall ratio*	Soil erosion (ton ha^{-1})*
UT1	Old production forest	555	14.3 a	0.03 a	5.86 a
UT2	Young production forest	492	13.2 a	0.03 a	1.47 a
UT3	Agroforestry	476	203.3 b	0.43 b	120.98 b
UT4	Arable land	556	225.7 b	0.41 b	163.22 b
LSD			46.3	0.09	87

b. Midstream Rejoso watershed

Code	Land cover	Ranfall (mm)	Runoff (mm)*	Runoff/ rainfall ratio*	Soil erosion (ton ha^{-1})*
MT1	Old production forest	616	80.2 a	0.13 a	3.07 a
MT2	Agroforestry	841	316.3 c	0.38 b	2.88 a
MT3	Agroforestry	616	228.8 b	0.37 b	6.63 ab
MT4	Agroforestry	541	344.9 c	0.64 c	10.33 b
LSD			86.6	0.12	4.22

**The same letter indicates no statistically significant differences between location with Fisher's LSD test ($p<0.05$).*