ການປະເມີນລະດັບນ້ຳໄຫຼບ່າໜ້າດິນ ຈາກການນຳໃຊ້ດິນບາງປະເພດ ຂອງຊາວກະສິກອນ ໃນເຂດພື້ນທີ່ດິນຄ້ອຍຊັນ

ໂອນກາ ວິຊຽກ[1], ໂອລິເວ ຣິໂບນຊີ[2], ອາແລງ ປີແອເຣ[2] , ໂອລິດ ແສງຕາເຮືອງຣຸ່ງ[3], ຄຣິສຕຽນ ວາເລນຕິນ[4]

ບົດຄັດຫຍໍ້

ວິທີປະເມີນລະດັບນ້ຳໄຫຼບ່າໜ້າດິນ, ດ້ວຍວິທີ CN ແມ່ນວິທີການທີ່ເໝາະສົມ ສຳລັບວຽກວາງແຜນອານຸລັກດິນ ແລະ ນ້ຳ. ຍ້ອນວ່າ ວິທີການດັ່ງກ່າວ ເປັນວິທີການທີ່ກະທັດຮັດ ຊຶ່ງປະກອບດ້ວຍຫຼາຍຮູບແບບ ຂອງຄ່າປະເມີນການເຊາະເຈື່ອນດິນ. ແຕ່ຍ້ອນຂາດຖານຂໍ້ມູນທີ່ລະອຽດ ສຳລັບພືດໃນເຂດອາຊີຕາເວັນອອກສ່ຽງໃຕ້, ຈຶ່ງເປັນສາເຫດເຮັດໃຫ້ວິທີການດັ່ງກ່າວ ບໍ່ໄດ້ຖືກນຳໃຊ້ຢ່າງກວ້າງຂວາງ ເທົ່າທີ່ຄວນ.

ຈຸດປະສົງຂອງວຽກທີ່ໄດ້ກ່າວໃນບົດນີ້ ແມ່ນເພື່ອດັດປັບວິທີການດັ່ງກ່າວ ໃຫ້ເໝາະສົມກັບເງື່ອນໄຂທ້ອງຖິ່ນຂອງພາກເໜືອ ໃນການປະເມີນຄ່າການເຊາະເຈື່ອນດິນ ສຳລັບພືດຕ່າງໆ. ວິທີການ CN ແມ່ນແທດເໝາະກັບເງື່ອນໄຂຂອງ ລາວ, ໂດຍເນັ້ນໃສ່ຄວາມຄ້ອຍຂອງຊະນິດດິນ ຊຶ່ງເປັນປັດໄຈຕົ້ນຕໍ ທີ່ເຮັດໃຫ້ມີນ້ຳໄຫຼບ່າ. ໃນການປະເມີນຄ່າ CN ແມ່ນໄດ້ນຳໃຊ້ຂໍ້ມູນນ້ຳຝົນ - ນ້ຳໄລບ່າຈາກແປງທົດລອງຂະໜາດນ້ອຍ ເປັນເວລາ 3 ປີ (2003 - 2005) ແລະ ຈາກອ່າງເກັບນ້ຳໄຫຼບ່າ ເປັນເວລາ 2 ປີ (2005 - 2006) ໃນລະດູຝົນ ທີ່ຫ້ວຍປ່ານໍ່ ແຂວງຫຼວງພະບາງ.

ປະສິດທິພາບຂອງວິທີການ CN ໃນການຄຳນວນນ້ຳໄຫຼບ່າ ແມ່ນປະເມີນດ້ວຍຄ່າຄາດເຄື່ອນຂອງຮາກຂັ້ນສອງສະເລັ່ຍ ແລະ ຕົວຄູນຂອງມາດຖານທີ່ກຳນົດ. ສຳລັບພືດອາຍຸສັ້ນ (ເຂົ້າໄຮ່, ສາລີ, ໝາກເດືອຍ) ຄ່າການປະເມີນ ແມ່ນມີຄວາມຊັດເຈນສູງ ແຕ່ສຳລັບພືດອາຍຸຍາວ (ໄມ້ສັກ, ກ້ວຍ, ໄມ້ປ່ອງ) ຄ່າປະເມີນແມ່ນມີຄວາມຊັດເຈນຕ່ຳ ຫາ ປານກາງ. ສຳລັບພືດອາຍຸຍາວ, ຂະໜາດຂອງເຮືອນຍອດ ຈະມີຜົນກະທົບສູງ ຕໍ່ການກະຈາຍຂອງນ້ຳໄຫຼບ່າໜ້າດິນ.

ຄຳສັບຫຼັກ: ວິທີການປະເມີນລະດັບນ້ຳໄລບ່າໜ້າດິນ CN, ແປງທົດລອງຂະໜາດນ້ອຍ, ອ່າງເກັບນ້ຳໄຫຼບ່າ, ໄມ້ສັກ, ກ້ວຍ, ໄມ້ປ່ອງ, ເຂົ້າໄຮ່, ສາລີ ແລະ ປ່າໄມ້.

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[4]ສະຖາບັນ ຄົ້ນຄວ້າ ເພື່ອການພັດທະນາ (IRD - France)

Estimation of runoff curve number (CN) of some Laotian land use types

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Abstract

The Natural Resources Conservation Service runoff curve number (CN) is a well established method to estimate runoff for soil and water conservation design purposes. Because of its simplicity, the method is incorporated in several erosion models. The lack of extensive databases for Southeast Asian crops, however, hinders its application to the region.

The objective of this paper was to adapt the method to northern Lao conditions and estimate runoff CN values for several crops and common vegetation types of the region. The CN method was adapted to Laotian conditions by emphasizing the role of slope over soil type as a factor driving runoff generation. Event rainfall-runoff data collected in microplots over three years (2002-2005) and in open troughs over two (2005-2006) monsoon seasons in Houay Pano catchment (Luang Prabang Province) formed the basis for CN values estimation.

The effectiveness of CN method to reproduce observed runoff was assessed by root mean square error and coefficient of determination criteria. While for annual crops (upland rice, maize, Job's tears) the method appeared reliable, for several perennial crops (teak, banana, bamboo) CN method predictions resulted only in fair or poor goodness-of-fit. For these vegetation types, the small scale of observations (< 2.5 m2) in comparison with the canopy size may have influenced the scatter of runoff observations and the poor performance of the CN method.

Key words: *CN runoff curve method; microplot; open trough; teak; banana; bamboo; upland rice; Job's tears; maize; forest.*

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Introduction

The Natural Resources Conservation Service curve number (CN) (USDA, 1986) is a well-know method to predict storm runoff. The method is based on the unit hydrograph approach, whereby only a part of the storm rainfall contributes to the runoff (Beven, 2001). The method is popular for soil and water conservation design, and forms the basis of several erosion models worldwide (Borah and Bera, 2003).

Part of its popularity is due to the extensive database created by USDA for most common soils and crops of temperate western areas. However, for Southeast Asian conditions CN reference values are lacking. In the literature, the authors could found only very few estimates of CN values that referred to general groups of land use types and were derived from published work for application to catchment scale modelling rather than field data (Ruslan et al., 2002; Shrestha et al., 2006). The lack of reference values hinders the application of the CN method to the Southeast Asian region. Moreover, field research showed that in the tropical mountains of Southeast Asia, topography plays a more important role in runoff generation than soil type (Janeau et al., 2003; Chaplot et al., 2007). On gentle slopes, rainfall impact induces the formation of soil crusts that inhibits infiltration. On steep slopes, formation of crusts is prevented by the topographic setting, and runoff generation is comparatively lower.

The objective of this paper was to adapt the CN method to northern Lao conditions and to estimate CN values for several cultivated and non-cultivated land use types common in northern Laos. Estimations were based on an extensive event rainfall-runoff database collected during the Management of Soil Erosion Consortium (MSEC) research programme in Houay Pano catchment, Luang Prabang Province (e.g. Chaplot et al., 2007).

Materials and methods

The CN curve number method. In CN method, event runoff is generated according to the equation:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (1)$$

where Q = runoff (mm); P = rainfall (mm), and S = soil storage capacity (mm). If P <0.2S, then Q = 0. The soil storage capacity S is estimated as:

$$S = 254\left(\frac{100}{CN} - 1\right) \qquad (2)$$

where CN is the curve number, a dimensionless number ranging from 30 to 100. The higher the CN, the higher the runoff. CN depends on land use type, soil, and Antecedent Soil Moisture (AMC) conditions. Soils are classified into four hydrologic groups, from A, i.e. freely draining soils, to D, i.e. soils prone to saturation. The base CN value for a given land use (crop) and soil type at normal soil moisture condition is CN2. Adjustments are applied for Antecedent Moisture Conditions (AMC), i.e. normal, dry, or wet. Both the definition of dry or wet conditions and the procedure to adjust CN values according to moisture conditions changed over time (Bhuyan et al., 2003). Generally speaking, dry conditions (CN1) are close to soil moisture at wilting point or drier, and wet conditions (CN3) correspond to field capacity or wetter. In several catchment models (Borah and Bera, 2003), adjustments for dry conditions are done by calculating CN1 as the largest value between:

$$CN_1 = 0.4CN_2 \qquad (3)$$

or

$$CN_1 = CN_2 - \frac{20(100 - CN_2)}{100 - CN_2 + \exp(2.533 - 0.0636(100 - CN_2))} \qquad (4)$$

Wet conditions are accounted for by estimating CN3 as:

$$CN_3 = CN_2 \exp(0.00673(100 - CN_2))$$

The original procedure that generated reference CN values for common crops in the U.S. consisted of (i) selecting from a large database the annual maximum daily runoff and associated rainfall for each soil type and land cover; and (ii) inverting equations (1) and (2) to calculate the CN value. The median CN value of the series was considered occurring at average antecedent soil moisture conditions (CN2; Bhuyan et al., 2003).

Adaptation of CN method. In this study, CN values were estimated from event rainfall-runoff measurements conducted using 1-m2 microplots from 2002 to 2005 in the headwater catchment of Houay Pano, northern Lao PDR (Chaplot et al., 2007; C. Valentin, pers. comm.). In addition, event rainfall-runoff measurements conducted in 2005 and 2006 on riparian sites instrumented with open troughs in the same catchment (Vigiak et al., 2006; in press) were used to estimate CN values of riparian vegetation types.

The original procedure to estimate CN2 values and to apply the CN method was modified in several ways. In order to take into account slope influence effect on runoff generation (Janeau et al., 2003; Chaplot et al., 2007), microplot data were separated in two slope classes, gentle (microplot slope < 60%), and steep (microplot slope > 60%). The soil hydrologic classification of the original CN method was instead disregarded.

Because of the limited data set, rather than selecting only the maximum annual runoff event for each crop-slope category, we kept all storm events, and selected the maximum runoff of each event. Event antecedent moisture conditions (AMC) were estimated using Casenave and Valentin (1992) moisture index ik as a proxy. Dry conditions were set at ik < 4.4, whereas wet conditions were set at ik > 36. These two limits corresponded to the 10th and 90th percentile of the ik index distribution of the dataset.

For all crop-slope categories, the CN method was applied using all possible CN values from 30 to 99. First, CN were adjusted for event antecedent moisture conditions, i.e. by applying eqs. (3) and (4) if ik index indicated dry conditions, or eq (5) if ik index indicated wet conditions. Then, equations (1) and (2) were applied to the crop-slope dataset.

Assessment of goodness-of-fit of CN method predictions. Goodness-of-fit of the runoff predictions obtained with the CN method were assessed against observations by calculating the root mean square error (RMSE) as defined by:

$$RMSE_i = \sqrt{\frac{\sum (R_{CNi,y} - R_{o,y})^2}{n-1}} \qquad (6)$$

where for any CNi = 30-99, RCNi,y = runoff predicted by CN method with CNi for the event y, n = number of events, and Ro,y = runoff observed in the eventy.

The second goodness-of-fit criterion was the coefficient of determination (CD):

$$C_{D,i} = 1 - \frac{\sum (R_{CNi,y} - R_{o,y})^2}{\sum (R_{o,y} - \overline{R}_o)^2} \qquad (7)$$

where = average observed runoff of the crop-slope category. The CNi value that best matched observations according to the two criteria was set as the CN2 value of that crop-slope category.

Results and discussion

Microplot rainfall-runoff dataset encompassed 335 crop-event entries including nine crop/land use types (upland rice, maize, Job’s tears, forest, fallow, and teak). Open trough data comprised 144 crop-event entries including three riparian vegetation types (native grass, banana, and bamboo).

Table 1 indicates the CN values that best matched runoff observations, the number of entries available for each crop, the average observed and CN-predicted runoff, and the goodness-of-fit criteria scores. In most cases, high coefficients of determination indicated good performance of the CN method. However, there was a large scatter between observed and predicted runoff (Figures 1, 2 and 3). This is mainly because the CN method was applied to all events, while it originally was designed for yearly maximum storms. By using all events, we retained a larger scatter in the runoff response. CN values were comparable to those reported in the literature (Ruslan, 2004; Shrestha et al., 2006) or to USDA reference values for soils type B, i.e. average draining soils such as those of Houay Pano catchment.

For cultivated crops, differences in runoff response between steep and gentle setting were negligible, and the slope subdivision was therefore dropped. Also, the dataset for maize was small (35 observations) and indicated a rainfall-runoff response similar to the upland rice, so the two crops were merged. Runoff generation was much lower under Job's tears than under upland rice and maize. This is in agreement with de Rouw et al. (2002) observations that Job's tears, which establishes quickly, hence covers soil early and effectively, is potentially better at conserving soil and water than upland rice.

For banana, teak and bamboo, the CN method poorly predicted observed runoff, as shown by negative coefficients of determination. This is probably due to the relatively small datasets available for these crops. Moreover, the scale at which measurements were made (1 m2 for microplots, around 2.5 m2 for open troughs) was small in comparison with the size of the plant canopies studied, and may have not been sufficient to fully represent runoff under these canopies.

Lower CN for banana fields reflected the fact that a good ground cover was always present under the banana canopies in this catchment (Vigiak et al., 2006; in press). The very high CN value of teak may be unexpected for a tree plantation, however when teak is cultivated without cover crop, as it is the case in Houay Pano, runoff and erosion under teak canopies tend to be high (Purwanto and Soerjono, 1989; Kolmert, 2001; Zimmermann et al., 2006). Runoff response was also very high under bamboo, especially on steep slopes.

On gentle slopes, fallow generated as much runoff as cultivated crops, however on steep slopes runoff generation under fallow was very low (Table 1). Native grass was the land use type that generated less runoff. However, only measurements of native grass on riparian land were available, so results for this land use should not be generalized to other landscape positions. Fallow on steep slopes generated even less runoff than forest; this is because the Dipterocarpus forest of Houay Pano has very open canopies and grows on Inceptisols, where infiltration is very limited (Chaplot et al., 2007). Indeed, results from forest runoff are close to poor woodland on soil type C of the USDA reference dataset.

Conclusions

The runoff curve number method was adapted to Laotian conditions by considering slope to be a more important factor controlling runoff generation than soil type. The land uses that generated less runoff were fallow and (in riparian area) native grass, especially on steep slopes. In contrast, high runoff generation occurred under teak and bamboo.

CN values of Table 1 are to be considered a first estimate suitable for some Laotian crops and land uses. However, they suffer from several limitations, namely being derived from 1) event-based rather than yearly-based maximum rainfall-runoff, 2) a rather limited dataset, and 3) very small scale of observation. These limitations must be borne in mind, and the CN values in Table 1 should be handled with care for application to other areas.

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Table 1: Estimation of CN2 values for Houay Pano land uses; n indicates the number of observations; RMSE is the root mean square error; CD is the coefficient of determination.

Land use			CN_2	n	Average observed runoff	Average CN- predicted runoff	RMSE	C_D
					mm	mm		
crop	Upland rice and maize		80	160	14.8	14.7	16.93	0.84
	Job's tears		72	137	6.5	6.5	10.20	0.96
	Banana§		67	54	11.3	11.4	14.09	-0.10
	Teak		82	52	24.4	24.6	18.20	-0.07
Non-crop	Forest		77	93	8.8	8.6	12.15	0.98
	Fallow	< 60%	78	102	13.8	13.9	13.38	0.77
		> 60%	58		4.4	4.3		
	Native grass§	< 60%	53	54	5.4	5.3	6.17	0.84
		> 60%	49		4.2	4.0		
	Bamboo§	> 60%	79	36	19.6	19.9	25.40	-0.19
		< 60%	93		37.8	37.0		

§Data from 2005 and 2006 riparian open trough measurements (approx. scale of observation = 2.5 m^2; Vigiak et al., in press). All other data estimated from 1 m^2 microplots.

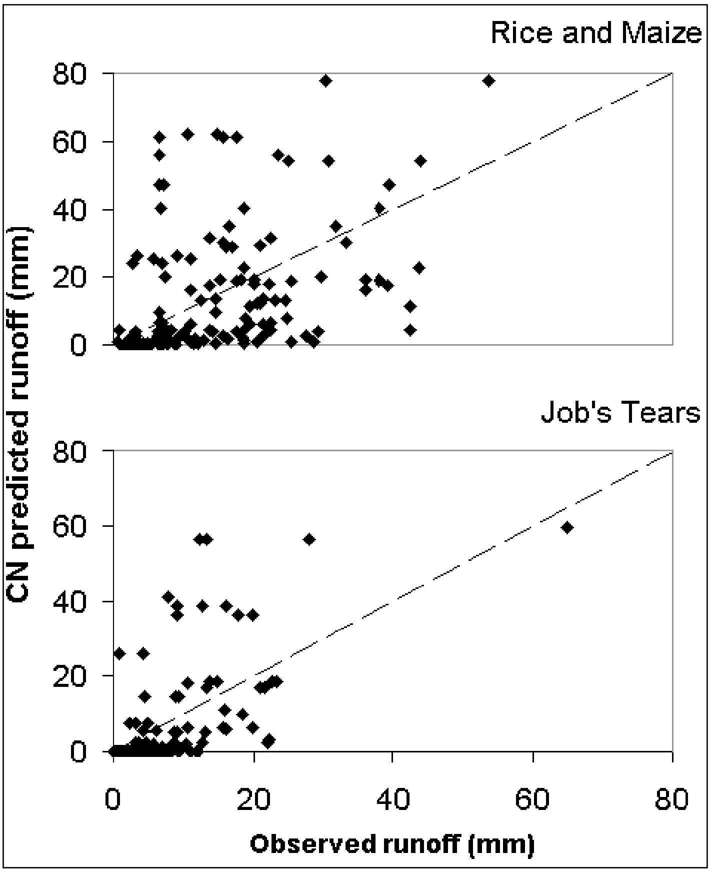

Figure 1: Observed runoff (mm) versus CN method predicted runoff (mm) for several annual crops (upland rice and maize, Job's tears) land use types of northern Lao PDR, Houay Pano catchment.

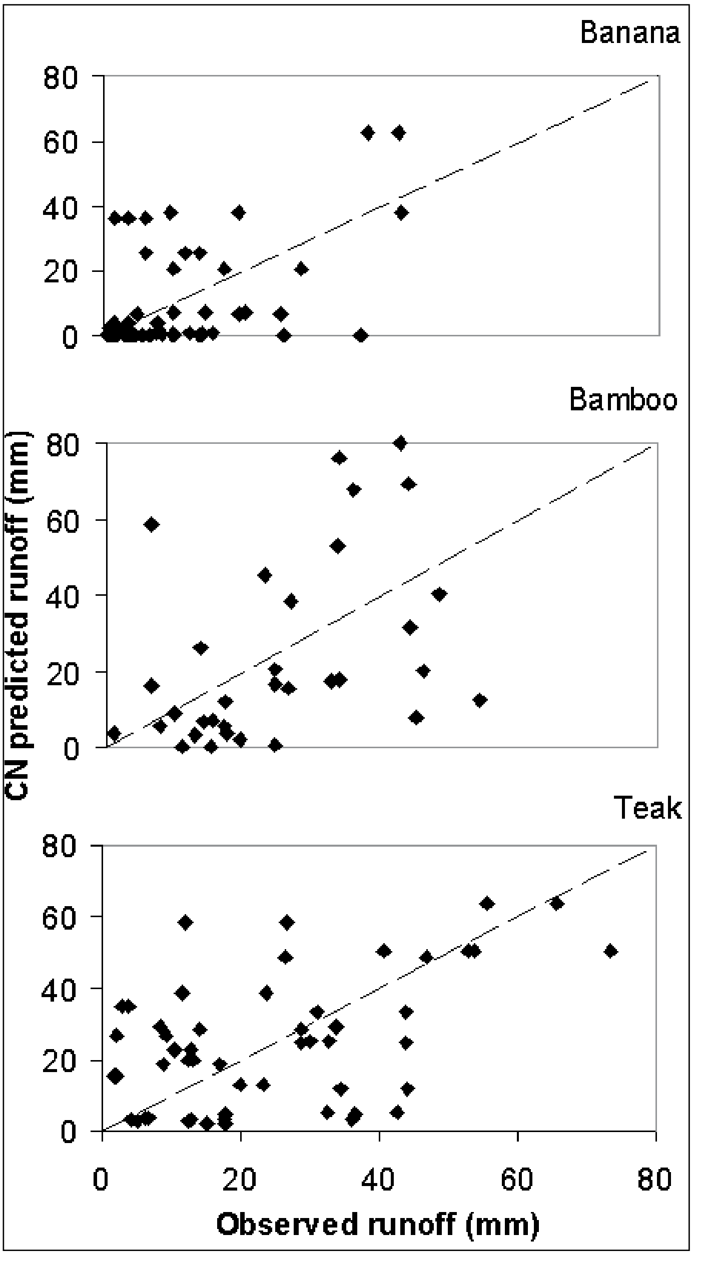

Figure 2: Observed runoff (mm) versus CN method predicted runoff (mm) for several perennials (banana, bamboo and teak) land use types of northern Lao PDR, Houay Pano catchment.

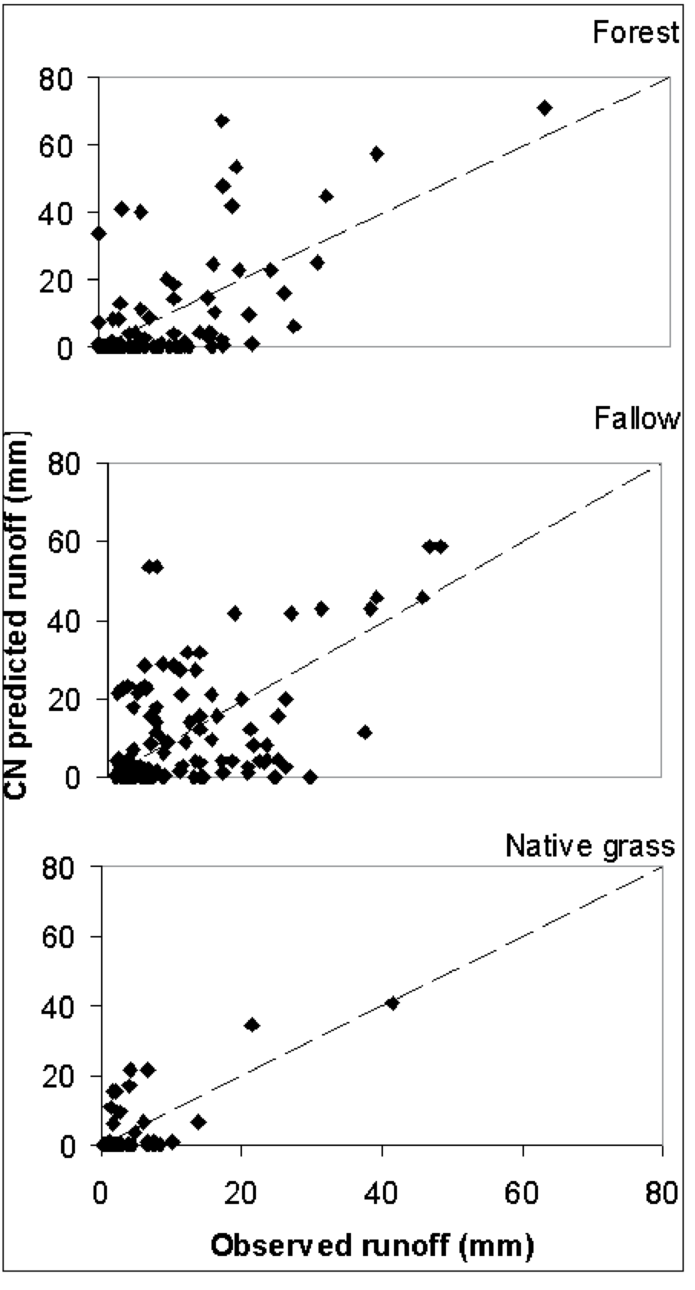

Figure 3: Observed runoff (mm) versus CN method predicted runoff (mm) for non-cultivated (forest, fallow and native grass) land use types of northern Lao PDR, Houay Pano catchment.