Ecohydrological Consequences in Transformative Landscape and Climate Change at Thadee Watershed, Nakhon Srithammarat Province

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Abstract

This research aimed at assessing conditions and trends of water quantity and sediment yield as the results of transformative landscape and climate change between 2009 and 2020 at Thadee watershed in Nakhon Srithammarat Province. The methodology comprised of four main steps, including 1) data collection; 2) future land use prediction; 3) water yield prediction; and 4) assessment of soil erosion. The results revealed that intact forest in 2009 will increase from 46.03% of the watershed to 56% in 2020 under trend scenario, and will be 56, 43 and 58% under local needs, development and watershed conservation scenarios, respectively. If amount of rainfall was treated constraint, estimated water yields derived from different land use scenarios were similar for the entire watershed, but water yields were predicted significantly different in the upper and middle sub-watersheds. In addition, estimated on-site soil erosion derived from development scenario was nearly two folds of watershed conservation scenario.

Keywords: Climate Change, Ecohydrology, Ecosystem Services, Landscape, Thadee Watershed

Introduction

Tropical ecosystems are changing across the developing countries and will be transformative for ecosystem processes, especially water regulation. Such changes are being driven by the dual change drivers of intensifying land use and climate change (Wilcox *et al*., 2011) and they are expected to accelerate in the future. Ecohydrology is defined as an interdisciplinary field studying the interactions between water and ecosystems. Areas of research include transpiration and plant water use, adaption of organisms to their water environment, influence of vegetation on stream flow and function, and feedbacks between ecological processes and the hydrological cycle (Zalewski *et al*., 1997).

The Thadee watershed located in Nakhon Srithammarat Province was selected by this research because it is recognized as vulnerable for landslide and flash flood. The watershed covers approximately 112 km^2 and its altitude ranges from 60 m to 1,835 m. These natural disasters are more severe and more visible nowadays. According to the measurement data at the outlet during 2000-2010, and average annual rainfall was 2,825 mm and the average annual water yield was 222.68 million m^3 (Bansopit *et al*., 2004). Water supply from the watershed is the main source for agriculture and household consumption in Nakhon Srithammarat municipality. However, land use/land cover of the watershed is being driven by rapid expansion of rubber plantation, uncertainty of fruit tree prices, and modernized rural development.

Therefore, appropriate management strategies for dealing with its consequent effects will be a critical priority for responsible agencies and stakeholders in the coming decades.

Methodology

Consultation meetings for stakeholders in the Thadee watershed were conducted to define four land use scenarios in 2020, namely 1) trends or business as usual scenario; 2) local needs scenario; 3) development scenario); and 4) watershed conservation scenario. In addition, CLUE-s model (Verburg and Veldkamp, 2004) was used to allocate the above land use scenarios. Average rainfall during 2000-2010 was obtained from the Thadee Watershed Research Station and climate data in 2020 were downloaded from WorldClim database.

The InVEST model and ArcGIS were used to calculate annual water yield (Tillis *et al*., 2011). Input parameters in the model included annual precipitation, soil depth, annual reference evapotranspiration (ETo), plant available water content (PAWC), land use/land cover, watershed, sub-watershed, maximum root depth and evapotranspiration coefficient. It is note that ETo was calculated from the ‘modified Hargreaves’ equation as below:

$$ETo = 0{:}0013 \times 0{:}408 \times RA \times (Tav + 17) \times (TD - 0{:}0123P)^{0.76}$$

The ‘modified Hargreaves’ uses the average of the mean daily maximum and mean daily minimum temperatures (Tavg in ^{o}C), the difference between mean daily maximum and mean daily minimums (TD), RA is extraterrestrial radiation (RA in $MJm^{-2}d^{-1}$) and precipitation (P in mm per month) (Subburayan *et al*., 2011). The raster grid of PAWC was obtained from soil texture and organic matter and equation developed by Saxton and Rawls (2006). The estimated water yields were calibrated against actual measurement data from 2007 and 2009.

Universal Soil Loss Equation (USLE) (Wieschmeier and Smith, 1978) was employed to calculate on-site soil erosion. USLE predicts long-term values (effects of sub-processes are lumped) as a function of erosivity (forces applied to the soil by the erosive agents) and erodibility (susceptibility of the soil to erosion) factors using the following mathematical equation

$$A = R \times K \times LS \times C \times P$$

where A = average annual soil loss (t/(ha/year)), R = rainfall/runoff erosivity factor ((MJ mm)/(ha h)), K = soil erodibility factor ((t/ha)/(MJ mm)), LS = slope length factor, C = cover management factor, and P = supporting practices factor.

Results and Discussion

Predicted water yields in 2020

The results of InVEST model revealed that if land use is changed according to land demand scenarios, the expected water yield will be 138-141 million m^3 for predicted annual rainfall of 1,980 mm, 223-225 million m^3 for average annual rainfall of 2,285 mm and 335-338 million m^3 for extreme rainfall of 3,838 mm (Table 1). It is note that the predicted annual water yields of the entire watershed are quite similar for all different scenarios but the results of analysis of variance (ANOVA) showed that they are significantly different for upstream and middle stream catchments. The results were consistent with findings of Hamilton and King (1983), which indicated that water flow was not significantly different between forested and non-forested areas in downstream or flat area.

Table 1 Predicted water yields in 2020 derived from different scenarios

	Predicted water yields (millon m³)		
Land use scenarios	**Extreme rainfall (3,838 mm/year)[1]**	**Average rainfall (2,528 mm/year)[2]**	**Climate change (1,980 mm/year)[3]**
Trends	335.6	222.04	138.82
Local needs	336.8	223.34	140.03
Development	338.7	225.04	141.33
Conservation	335.4	221.84	138.64

Notes: [1] rainfall in 2000; [2] average rainfall during 2000-2010; [3] predicted rainfall in 2020 derived from WorldClim

Estimated sediment

The total sediment was predicted highest for the combination of development land use scenario and extreme rainfall and lowest for the combination of trend land use scenario and climate change. This is due to rainfall/runoff erosivity factor has been recognized as the most important factor to generate soil erosion in the USLE model (Wieschmeier and Smith, 1978). In addition, estimated sediment derived from conservation land use scenario was predicted as the lowest compared to the remaining scenarios. It is approximately 60% of the total sediment yield generated from development land use scenario (Table 2).

Table 2 Estimated on-site sediment

	Sediment (ton/year)		
Land use scenarios	**Extreme rainfall (3,838 mm/year)[1]**	**Average rainfall (2,528 mm/year)[2]**	**Climate change (1,980 mm/year)[3]**
Trends	514,447	275,249	262,643
Local needs	533,386	285,426	272,393
Development	813,294	435,664	416,106
Conservation	491,436	262,894	250,836

Notes: [1] rainfall in 2000; [2] average rainfall during 2000-2010; [3] predicted rainfall in 2020 derived from WorldClim

Conclusion

This research focus on understanding and prediting the effects of the combination of transformative land use and climate change on water yield and sediment load. The results clearly showed that intensifying land use change due to rapid expansion of rubber plantation will generate huge sediment load and overland flow due to force of rainfall and less evapotranspiration from vegetation. The outputs of this research is being used by the Enhancing Economic and Financial Tools for Biodiversity and Ecosystem Services in South-East Asia Project (ECO-BEST) to persuade the municipality and downstream people to contribute money for maintain ecosystem processes, so called "*payment for ecosystem serives*".

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