Effects of strip thinning on suspended sediment yields using paired-catchment analysis

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1. INTRODUCTION

Paired-catchment approach has been widely applied for detecting the effects of forest management with hydrology (Hewlett, 1971). Changes in the suspended sediment yields (SSY) due to forest harvesting were combined impacts of changes in hydrological responses and sources of SSY (Asselman, 1999). Dung et al., (2013) showed that catchment runoff increased 227 to 667 mm after 50% of forest thinning depending on the size of drainage areas. However, changes in SSY was never been examined using paired catchment approaches, particularly for 50% of commercial thinning. We examined (1) changes in suspended sediment yield using paired catchment experiment after forest thinning; (2) compared to the order of magnitude of chances compared to the other studies.

2. STUDY SITE AND METHOD

This study is conducted in two small headwater catchments (K2- 0.17 km^2, K3- 0.02 km^2) covered by 20-50 yrs Japanese cypress (*Chamaecyparis obtusa*) and cedar plantations (*Cryptomeria japonica*) at Field Museum (FM) Karasawayama in Tochigi prefecture (E 36.36 N 139.60) (Fig. 1).

Mean precipitation is 1,239 mm and mean annual temperature is 13.9°. The altitude ranges from 90 to 290 m above the sea level. Dominant hillslope gradient ranges from 20 to 45°. The underlined geology is consisted of sedimentary rock.

Discharge and turbidity of catchment K2 and K3 was monitored from September, 2010 to February, 2012. Because 50% thinning of Japanese cypress and cedar of K2 was removed by machine with skid trail installation (total length (626 m) and area (0.003 km^2)), we defined the period before thinning effects was pre-thinning, while post-thinning period was after thinning effects including thinning.

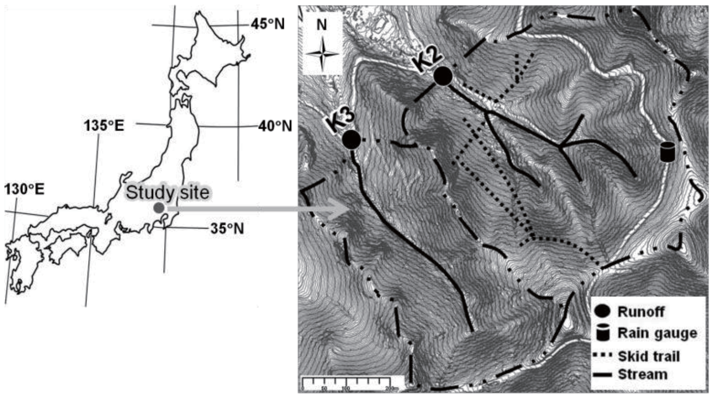

Fig. 1 Location of study catchment areas

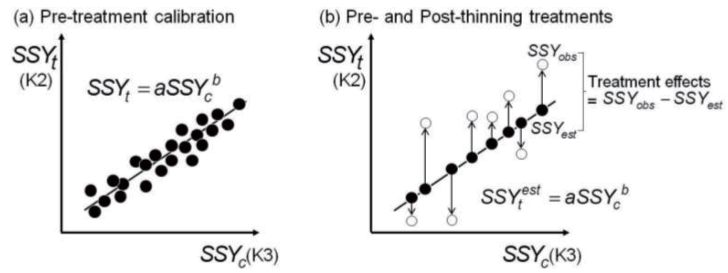

Fig. 2 Schematic illustration for paired-catchment analysis based on (a) pre-treatment calibration and (b) pre- and post-thinning treatments (Hewlett, 1982)

Paired-catchment approach was used on an assumption of SSY in control and treated catchments in pre- and post-thinning periods. This analysis can separate the changes in vegetation conditions from climate effects (Bosch and Hewlett, 1982). The calibration equation involved development of a regression of SSY between paired catchments (Fig. 2a). We then calculated the SSY of the post-thinning period in K2 using pre-thinning calibration. Treatment effects was estimated from observed SSY and predicted ones in K2 (Fig. 2b)

3. RESULTS AND DISCUSSDION

The pre-treatment regression was significant at a 90% confidence level (P = 0.09) (Fig.3a). Treatment effects of pre- and post-thinning periods also significantly differed (P = 0.04) (Fig.3b).

Greatest treatment effects were occurred storm events with large and small precipitation during thinning. In post-thinning period, estimated SSY was 1.0 t km^{-2} yr^{-1}, while observed SSY was in 2.0 t km^{-2} yr^{-1}. Therefore, we found that 200% of greater increases in SSY after thinning.

Dung et al. (2013) showed that runoff increases of treated catchment (1,931 mm yr^{-1}) were 2.6 times greater than one of the control catchment (735 mm yr^{-1}) in post-thinning period. Therefore, our SSY changes after thinning was similar at the order of magnitude of changes in hydrological responses.

We summarized the previous publications for changes in SSY after thinning and clear cut . Changes in SSY in these studies was ranged from 2 and 53 times compared to the previous studies (Table 1). Most of the previous studies were also reported that timber harvesting including cutting plus skid trial installation increased SSY. Because, skid trail installing increased slope gradient on cut and fill slopes in mountainous areas, hence skdi trial provide SS to stream. Our SSY in the post- thinning period (1.0 t km^{-2} yr^{-1}) tended to be lower than most of the previous studies. Beacase, our SSY based on the paried-catchment analysis was influenced by sptial specific results for minizing time effects, while SSY in single catchment analysis (Table 1) was impacted form both of individual spatial and temporal specific results. Therefore, we can expect that paired-catchment analysis would be likely to apply for effects on strip thinning on SSY because of maximizing treatment effects.

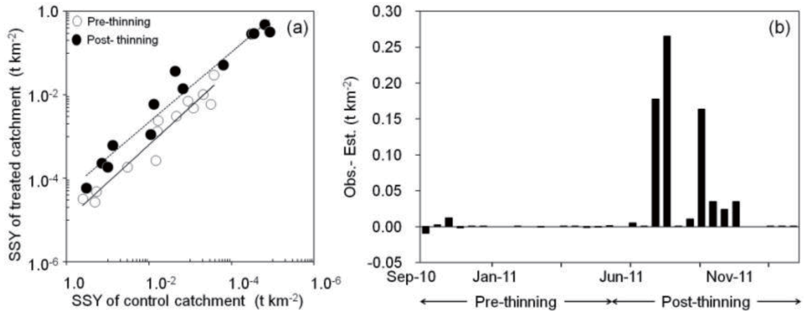

Fig.3 (a) Comparison on SSY in control and treated catchments; Straight and dotted line were calculated using regression analysis in pre- and post-thinning periods, separately; (b) Differences between observed and estimated SSY in pre- and post-thinning periods

Table 1. Summary on effects of thinning and clear cut on SSY

Area (km^2)	Thinning Treatment	SSY (t km^{-2} yr^{-1}) Pre	Post	Increase in SSY (times)	Reference
0.28	Selective thinning (25% of the stocking and 60-45 cm DBH)	10	30	3	Kasran & Nik (1994)
0.13	Selective thinning (cutting regimes : only 60 cm)	14	27	2	Kasran (1988)
0.30	Selective thinning (cutting regimes: 60-90 cm DBH)	7	12	2	Kasran (1988)
0.13	Forest to thinning (40% extraction unsupervisd)	14	27	2	Zulkifli et al. (1990)
10.00	Selective thinning (Steepland)	54	2826	53	Lai (1992)
0.5-1.0	Selective thinning	60	660	11	Dougla et al. (1992)
1.37	Slective thinning (20% of sub-basin)	0	1	8	Aderson and Potts (1987)
0.89	Clear cut (20%of the catchment)	24	44	2	Stott et al. (2001)
3.08	Clear cut	24	57	2	Leeks and Roberts (1987)
0.84	Clear cut	55	394	7	Freguson et al (1991)
6.85	Clear cut (progressive felling 50% of catchment)	19	116	6	Johnson (1993)
0.75	Clear cut (82%)	8	18	2	Beschta (1980)
0.96	Clear cut (100%)	14	170	12	Grant and Wolff (1991)
1.01	Selective thinning (25% patch cut)	150	260	2	Grant and Wolff (1992)
n/a	Logging	n/a	n/a	45	Megahan (1972)

n/a : Not available

4. SUMMARY

Our summaries are (1) forest thinning increased 2.0 t km^{-2} yr^{-1}, as observed SSY, and 1.0 t km^{-2} yr^{-1}, as estimated SSY by paired catchment analysis; (2) estimated SSY be more reliable than observed SSY for indentifying treatment effects due to maximizing spatial specific, while minimizing temporal specific; and (3) from previous studies and this study, increases in SSY after strip thinning were greater than careful management for minimizing soil compaction. We further need to analyze the sources of SSY using the nested catchment monitoring in K2.

REFERENCES

Dung BX, Gomi T, Onda Y, Kata H, Hiraoka (2013): Conference on Japan Society of Erosion Control Engineering, Shizuoka, Japan.

Hewlett JD (1971): Water Resources Bulletin **7**: 376-381.

Stednick (1996) : Journal of Hydrology **176**: 79-95.