Hydrological consequences of landscape fragmentation in mountainous northern Vietnam: Buffering of Hortonian overland flow

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Abstract: We use a hydrology-based fragmentation index to explore the influence of land-cover distribution on the generation and buffering of Hortonian overland flow (HOF) in two disturbed upland basins in northern Vietnam (Tan Minh). Both the current degree of fragmentation in Tan Minh and the current spatial arrangement of buffers (relative to HOF source areas) provide only limited opportunities for infiltrating surface runoff from upslope source areas, in part because of the high connectivity of swidden fields on long hillslopes. The intentional placement of buffers below HOF sources and the reduction of the down-slope lengths of swidden fields could reduce the occurrence of HOF on individual hillslopes. Reduction of the total watershed total depth of HOF would require maintaining a sufficient area of buffering land covers; and this may necessitate the use of longer fallow periods. These measures are, however, counter to the land-practice trends witnessed in the last several decades (i.e., no buffers, cultivation of long slopes, and increasingly shorter fallow periods). The two most likely scenarios of future land-cover change in Tan Minh-one representing increased fragmentation, the other decreased-both lead to an increase in HOF because of reduced buffering potential. The unlikely scenario of abandonment of agriculture and subsequent regeneration of forest, leads to both less fragmentation and less HOF. The study highlights the hydrological impacts associated with fragmentation at Tan Minh, which is the product of decades of local and regional forcing factors that have dictated the degree and timing of timber removal and swiddening at the site. ??

Author Keywords: Deforestation; Filter strips; KINEROS2; Land-cover conversion; Runoff generation; SE Asia; Swidden agriculture; Tropical watershed hydrology

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References:

1. Avissar, R., Peilke, R.A., A parameterization of heterogeneous land-surface for atmospheric numerical models and its impact on regional meteorology (1989) Month. Weath. Rev., 117, pp. 2113-2136
2. Bruijnzeel, L.A., (1990) Hydrology of Moist Tropical Forest and Effects of Conversion: A State of Knowledge Review, , IHP-UNESCO Humid Tropical Programme, Paris
3. Bruijnzeel, L.A., Forest hydrology (2000) The Forests Handbook, , Evans J.C. (Ed), Blackwell Scientific, Oxford, UK (Chapter 12)
4. Bruijnzeel, L.A., Hydrological functions of tropical forests: not seeing the soil for the trees? (2004) Agri. Ecosys. Environ., 104, pp. 185-228
5. Castella, J.-C., Gevraise, V., Novosad, P., Pham, H.M., Centralized planning and agricultural policy: the role of the state in the agrarian dynamics of Duc Van commune, Ngan Son District, Bac Kan Province, Viet Nam (2002) Doi Moi in the Mountains, Land use changes and farmers' livelihoods strategies in Bac Kan Province, Vietnam, pp. 99-119. , Castella J.C., and Dang K.Q. (Eds), The Agriculture Publishing House, Ha Noi, Viet Nam

6. Castella, J.-C., Pham, H.M., Suan, P.K., Villano, L., Tronche, N.R., Analysis of village accessibility and its impact on land use dynamics in a mountainous province of northern Vietnam (2005) Appl. Geog., 25, pp. 308-326
7. Cramb, R.A., Farmers' strategies for managing acid upland soils in Southeast Asia: an evolutionary perspective (2005) Agri. Ecosys. Environ., 106, pp. 69-87
8. Delang, C., Deforestation in Northern Thailand: the result of Hmong Farming Practices or Thai development trategies? (2002) Soc. Nat. Resour., 15, pp. 483-501
9. Donovan, D., Development in the local context: case studies from selected hamlets in five northern provinces (1997) Development Trends in Vietnam's Northern Mountain Region. Case Studies and Lessons from Asia, 2. , Donvan D., Rambo A.T., Fox J., Le Trong Cuc, and Tran Duc Vien T.D. (Eds), National Political Publishing House, Hanoi
10. Douglas, I., Hydrological investigations of forest disturbance and land cover impacts in South-East Asia: a review (1999) Philos. Trans. Roy. Soc. Biol. Sci., 354 (1391), pp. 1721-1897
11. Douglas, I., Greer, T., Sinun, W., Anderton, S., Bidin, K., Spilsbury, M., Suhaimi, J., Sulaiman, A.B., Geomorphology and rainforest logging practices (1995) Geomorphology and Land Management in a Changing Environment, pp. 309-320. , McGregor D.F.M., and Thompson D.A. (Eds), Wiley, Chichester, UK
12. Fox, J., Vogler, J.B., Land-use and land-cover change in montane mainland southeast Asia (2005) Environ. Manage., 36, pp. 394-403
13. Fox, J., Krummel, J., Yarnasarn, S., Ekasingh, M., Podger, N., Land use and landscape dynamics in northern Thailand: assessing change in three upland watersheds (1995) Ambio, 24, pp. 328-334
14. Fox, J., Minh Troung, D., Rambo, A.T., Nghiem Phuong Tuyen, Le Trong Cuc, Leisz, S., Shifting cultivation: a new old paradigm for managing tropical forests (2000) BioScience, 50, pp. 521-528
15. Fox, J., Leisz, S., Minh Troung, D., Rambo, A.T., Nghiem Phuong Tuyen, Le Trong Cuc, Shifting cultivation without deforestation: a case study in the mountains of northwestern Vietnam (2001) Applications of GIS and Remote Sensing in Biogeography and Ecology, , Millington A.C., Walsh S.J., and Osborne P.E. (Eds), Kluwer Academic Publishers, Boston, MA
16. Giambelluca, T.W., Hydrology of altered tropical forests (2002) Hydrol. Process., 16, pp. 1665-1669
17. Giambelluca, T.W., Ziegler, A.D., Nullet, M.A., Dao, T.M., Tran, L.T., Transpiration in a small tropical forest patch (2003) Agri. Forest Meteorol., 117, pp. 1-22
18. Hall, C.A.S., Tian, H., Qi, Y., Pontius, G., Cornell, J., Modelling spatial and temporal patterns of tropical land use change (1995) J. Biogeog., 22, pp. 753-757
19. Hillel, D., (1971) Soil and Water - Physical Principles and Processes, , Academic Press, New York
20. Horton, R.E., Rainfall interception (1919) Month. Weath. Rev., 47, pp. 603-623
21. Horton, R.E., The role of infiltration in the hydrologic cycle (1933) Eos Trans. AGU, 14, pp. 446-460
22. Hunter, (1996) Fundamentals of Conservation Biology, , Blackwell Science, Cambridge, MA
23. Hurni, H., Soil erosion in Huai Thung Choa-northern Thailand. Concerns and constraints (1982) Mount. Res. Develop., 2, pp. 141-156
24. Kapos, V., Effects of isolation on the water status of forest patches in the Brazillian Amazon (1989) J. Trop. Ecol., 5, pp. 173-185
25. Lal, R., (1987) Tropical Ecology and Physical Edaphology, , Wiley, New York
26. Lam, N.T., Patanothai, A., Rambo, A.T., Recent changes in the composite swidden farming system of a Da Bac Tay ethnic minority community in Vietnam's northern mountain region (2004) SE Asian Studies, 42, pp. 273-293
27. Laurance, W.F., Forest-climate interactions in fragmented tropical landscapes (2004) Phil. Trans. Roy. Soc. Lond. B, 359,

pp. 345-352

28. Laurance, W.F., Bierregaard Jr., R.O., Preface: a crisis in the making (1997) Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities, , Laurance W.F., and Bierregaard Jr. J.O. (Eds), University of Chicago Press, Chicago
29. Laurance, W.F., Laurance, S.G., Ferreira, L.V., Rankin-de Merona, J.M., Gascon, C., Lovejoy, T.E., Biomass collapse in Amazonian forest fragments (1997) Science, 278, pp. 1117-1118
30. Laurance, W.F., Ferreira, L.V., Rankin-de Merona, J.M., Laurance, S.G., Rain forest fragmentation and the dynamics of Amazonia tree communities (1998) Ecology, 79, pp. 2032-2040
31. Malmer, A., Gripp, H., Soil disturbance and loss of infiltrability caused by mechanized and manual extraction of tropical rainforest in Sabah, Malaysia (1990) Forest Ecol. Manage., 38, pp. 1-12
32. Mather, A.S., Needle, C.L., The forest transition: a theoretical basis (1998) Area, 30, pp. 117-124
33. Morgan, R.P.C., (1995) Soil Erosion and Conservation, , Longman Group Limited, Essex, UK
34. Parlange, J.-Y., Lisle, I., Braddock, R.D., Smith, R.E., The three-parameter infiltration equation (1982) Soil Sci., 133, pp. 337-341
35. Rambo, A.T., Defining highland development challenges in Vietnam (1995) The Challenge of Highland Development in Vietnam. Program on Environment, , Rambo A.T., Reed R.R., Le Trong Cuc, and DiGregorio M.R. (Eds), East-West Center, Honolulu, HI
36. Rambo, A.T., Tran Duc Vien, Social organization and the management of natural resources: a case study of Tat Hamlet, a Da Bac Tay ethnic minority settlement in Vietnam's northwestern mountains (2001) SE Asian Studies, 39, pp. 299-324
37. Rigg, J., Nattapoolwat, S., Embracing the global in Thailand: activism and pragmatism in an era of deagrarianization (2001) World Dev., 29 (6), pp. 945-960
38. Sadoulet, D., Castella, J.-C., Vu, H.N., Dang, D.Q., A short history of land use change and farming system differentiation in Xuat Hoa Commune, Bac Kan, Province, Viet Nam (2002) Doi Moi in the Mountains, Land use Changes and Farmers' Livelihoods Strategies in Bac Kan Province, Vietnam, pp. 21-46. , Castella J.C., and Dang K.Q. (Eds), The Agriculture Publishing House, Ha Noi, Viet Nam
39. Schmidt-Vogt, D., (1999) Swidden Farming and Fallow Vegetation in Northern Thailand, Geoecological Research, 8. , Franz Steiner Verland, Stuttgart, Germany
40. Sidle, R.S., Ziegler, A.D., Negishi, J.N., Abdul Rahim, N., Siew, R., Erosion processes in steep terrain - truths, myths, and uncertainties related to forest management in Southeast Asia (2006) Forest Ecol. Manage., 224, pp. 199-225
41. Skole, D., Tucker, C., Tropical deforestation and habitat fragmentation in the Amazon: satellite data from 1978 to 1988 (1993) Science, 260, pp. 1905-1910
42. Smith, R.E., Goodrich, D.C., Quinton, J.N., Dynamic, distributed simulation of watershed erosion: the KINEROS2 and EUROSEM models (1995) J. Soil Water Cons., 50, pp. 517-520
43. Smith, R.E., Goodrich, D.C., Unkrich, C.L., Simulation of selected events on the Catsop catchment by KINEROS2 A report for the GCTE conference on catchment scale erosion models (1999) Catena, 37, pp. 457-475
44. Thongmanivong, S., Fujita, Y., Fox, J., Resource use dynamics and land-cover change in Ang Nhai and Phou Phanang National Forest Reserve, Lao PDR (2005) Environ. Manage., 36, pp. 382-393
45. Tran Duc Vien, Soil erosion and nutrient balance in swidden fields of the composite swiddening agroecosystem in the northwestern mountains of Vietnam (1998) Land Degradation and Agricultural Sustainability: Case Studies from Southeast and East Asia. Regional Secretariat, the Southeast Asian Universities Agroecosystem Network (SUAN), , Paranothai A. (Ed), Khan Kaen University, Thailand

46. Tran Duc Vien, Culture, environment, and farming systems in Vietnam's northern mountain region (2003) SE Asian Studies, 41, pp. 180-205
47. Tran Duc Vien, Dung, Dung, N.V., Dung, P.T., Lam, N.T., A nutrient balance analysis of the sustainability of a composite swiddening agroecosystem in Vietnam's northern mountain region (2004) SE Asian Studies, 41, pp. 491-502
48. Turner, I.M., Species loss in fragments of tropical rain forest: a review of the evidence (1996) J. Appl. Ecol., 33, pp. 200-209
49. Williams-Linera, G., Domiguez-Gastelu, V., Garcia-Zurita, M.E., Microenvironment and floristics of different edges in a fragmented tropical rainforest (1998) Cons. Biol., 12, pp. 1091-1102
50. Xu, J.C., Fox, J., Vogler, J.B., Peifang, Z., Yongshou, F., Lixin, Y., Jie, Q., Leisz, S., Land-use and land-cover change and farmer vulnerability in Xishuangbanna Prefecture in southwestern China (2005) Environ. Manage., 36, pp. 404-413
51. Ziegler, A.D., Giambelluca, T.W., Importance of rural roads as source areas for runoff in mountainous areas of northern Thailand (1997) J. Hydrol., 196, pp. 204-229
52. Ziegler, A.D., Giambelluca, T.W., Sutherland, R.A., Nullet, M.A., Yarnasarn, S., Pinthong, J., Preechapanya, P., Jaiarree, S., Toward understanding the cumulative impacts of roads in agricultural watersheds of Montane Mainland Southeast Asia (2004) Agri. Ecosys. Environ., 104, pp. 145-158
53. Ziegler, A.D., Giambelluca, T.W., Tran, L.T., Vana, T.T., Nullet, M.A., Fox, J., Tran Duc Vien, Evett, S., Hydrological consequences of landscape fragmentation in mountainous Northern Vietnam: evidence of accelerated overland flow generation (2004) J. Hydrol., 287, pp. 124-146
54. Ziegler, A.D., Tran, L.T., Sidle, R.C., Giambelluca, T.W., Sutherland, R.A., Tran Duc Vien, Effective slope lengths for buffering hillslope surface runoff in fragmented landscapes in northern Vietnam (2006) Forest Ecol. Manage., 224, pp. 104-118
55. Zimmermann, B., Elsenbeer, H., De Moraes, J.M., The influence of land-use changes on soil hydraulic properties: implications for runoff generation (2006) Forest Ecol. Manage., 222, pp. 29-38