Portraying Two Decades of Land-Use Dynamics in an Urbanizing Tropical Watershed, Brantas River Basin, Indonesia

Bagus Setiabudi Wiwoho[1,2], Stuart Phinn[1], Neil McIntyre[3]

1. School of Earth and Environmental Sciences, the University of Queensland, Australia
2. Dept of Geography, Universitas Negeri Malang, Indonesia
3. Sustainable Mineral Institute, The University of Queensland, Australia

Introduction

Brantas River Basin (BRB) watershed is a tropical watershed experiencing rapid urbanization. This continuing pressure has been reported to trigger increasing occurrences of environmental issues such as drying up, lowland erosion, floods and sedimentation. Attempts to understand the landscape dynamics have been limited and information regarding the land-use dynamics is scattered.

Spatial land-use modeling is a widely used tool to investigate the land-use change in many areas. Yet, it lacks of room for inclusion of land-user perspective. This study examines land-use dynamics in BRB by using spatial model as well as by considering land-users point of view.

The study specifically aims at (1) characterizing the land-use changes in the BRB over the past two decades (1995 – 2015), (2) evaluating the spatial patterns of land-use transition processes in the BRB, and (3) identifying potential drivers of land-use change and how they differ between regional (provincial) and local (individual) scales.

Study Area

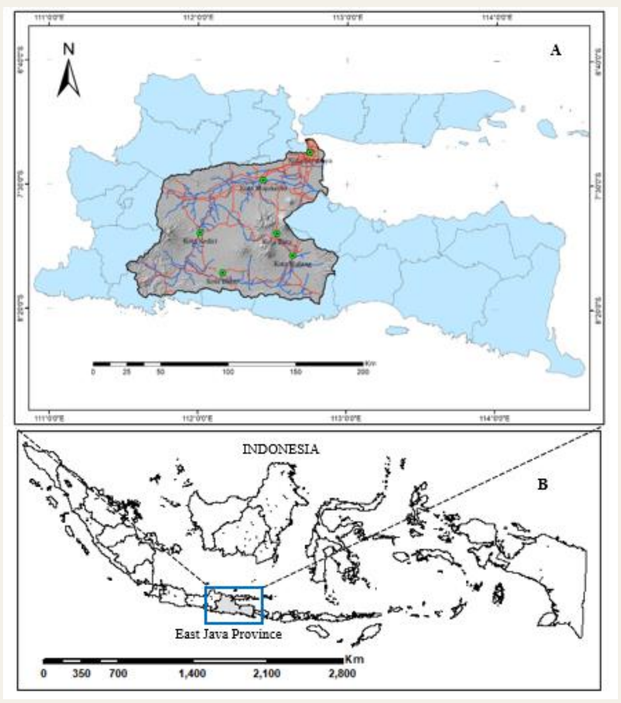

Figure 1. Brantas River Basin, East Java, Indonesia

The BRB, with an area of 11,832 km^2, covers approximately 30% of the province of East Java (Figure 1). The basin is home to two major cities and 13 regencies. The population grew from around 21 million in 2005 to 22.5 million in 2017, accounting for 54% of East Java's population and 7.5% of Indonesia's population. Seven mountains create large topographical variability. Elevation ranges from sea-level to 3,663m above sea-level. The BRB exhibits a typical tropical monsoon climate with two distinct seasons: a dry season (April-October) and a wet season (November-March) (Bhat, 2008). Recorded long-term annual rainfall (1995–2015) ranges from an average of 2000 mm/year to 4000 mm/year at high altitudes. The BRB represents a mixed rural and urban society, with potentially competing land-uses. Growing urbanization and industrialization have led to encroachment on remaining forests, especially in the upper basin.

Methods

The study employed several approaches. First, we used remote-sensing based Object Based Image Analysis to produce temporal land-use maps (1995, 2005, and 2015) using Landsat imageries and hierarchical rules (Kappa accuracy 83 – 87%). Second, we employed Land Change Modeler (LCM) to examine spatial drivers that explains the dynamics of land-uses in BRB. Twelve spatial drivers were derived to represents physical and socio-economic setting in BRB. Multi-Layer Perceptron (MLP) was used to model land-use transition types in BRB for two periods (1995-2015). Questionnaire-based information from land-users were collected to derive land-use drivers from user's perception. Agreement matrix was established to assess the drivers from spatial model and from individual perception.

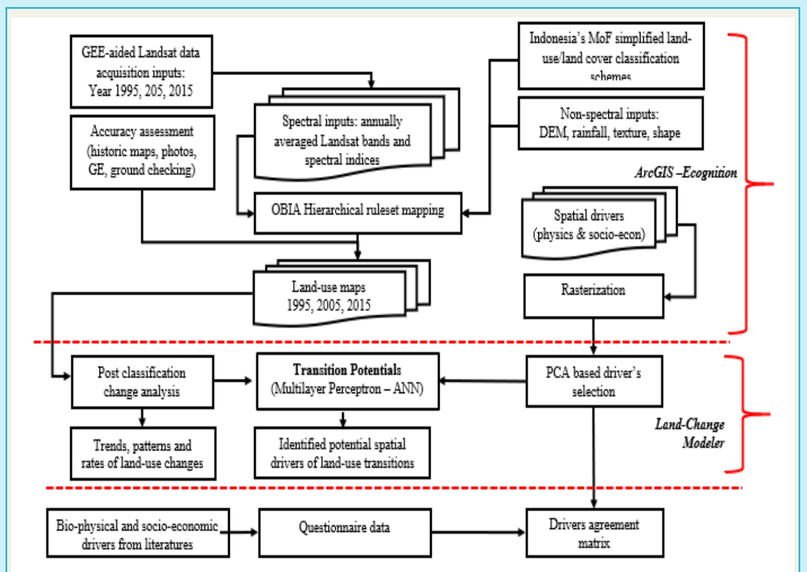

Figure 2. Research Approach

Results

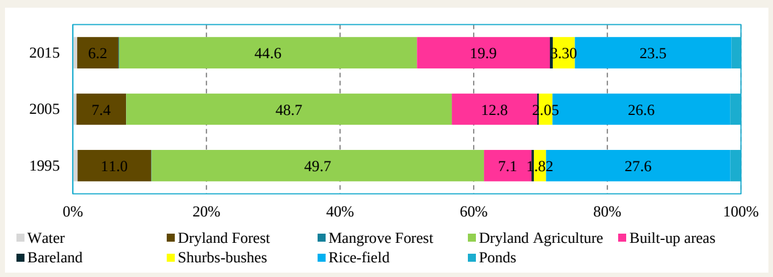

Figure 3. Land-use dynamics in BRB (1995-2015)

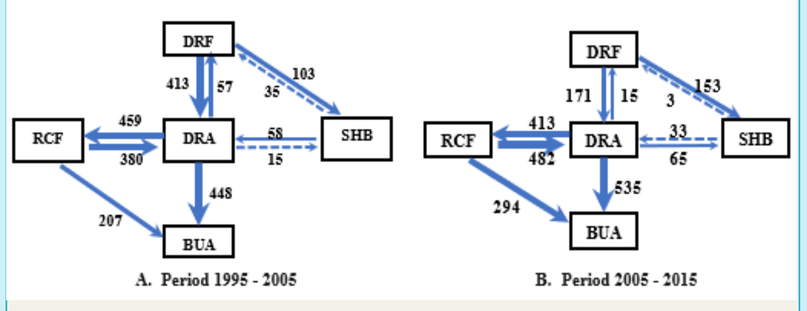

Figure 4. Major land-use transition types in BRB

Table 1. Model Performance and Relative Importance of Spatial Drivers in LCM

	Relative Importance of Each Driver for Each Land-use Transition									
	DRF to DRA	DRF to SHB	DRA to RCF	DRA to DRF	DRA to BUA	DRA to SHB	RCF to DRA	RCF to BUA	SHB to DRA	SHB to DRF
Dist_Road	4	2	5	4	1	4	2	2	2	2
Rainfall	10	5	12	10	11	11	12	8	12	6
Dist_City_Center	9	11	6	6	6	7	11	3	5	4
Elevation	3	1	1	3	2	2	3	10	1	1
Slope	11	9	11	11	3	8	8	9	11	11
Dist_Disaster_Zone	12	12	9	1	12	6	7	7	8	12
Dist_Reg_Dev_Zone	5	3	3	5	5	1	1	5	3	3
Dist_A_Econ_Zone	1	4	2	2	4	5	4	1	9	5
Dist_B_Econ_Zone	2	8	8	7	9	3	10	4	7	10
Dist_to_Agric_area	6	10	7	8	8	9	6	11	10	7
Dist_to_Forest	7	7	4	9	7	10	9	12	4	9
Dist_to_Tree_zone	8	6	10	12	10	12	5	6	6	8
Model Performance (R^2)	0.80	0.72	0.81	0.88	0.80	0.89	0.68	0.64	0.91	0.71

Five major land-uses in BRB encompass dryland forest, dryland agriculture, built-up areas, rice-field and shrubs. In two decades, BRB has undergoing fast urban development, continuing forest loss, and threats to loss of forest and agricultural lands for compensating urban expansion.

Land-use transitions were modelled with accuracies ranging from 0.64 to 0.91, with lowest accuracies involving urban transition. This implies the complex process pf urbanization in BRB.

Spatial drivers representing socio-economic setting such as road and city proximity plays a greater importance than physical drivers.

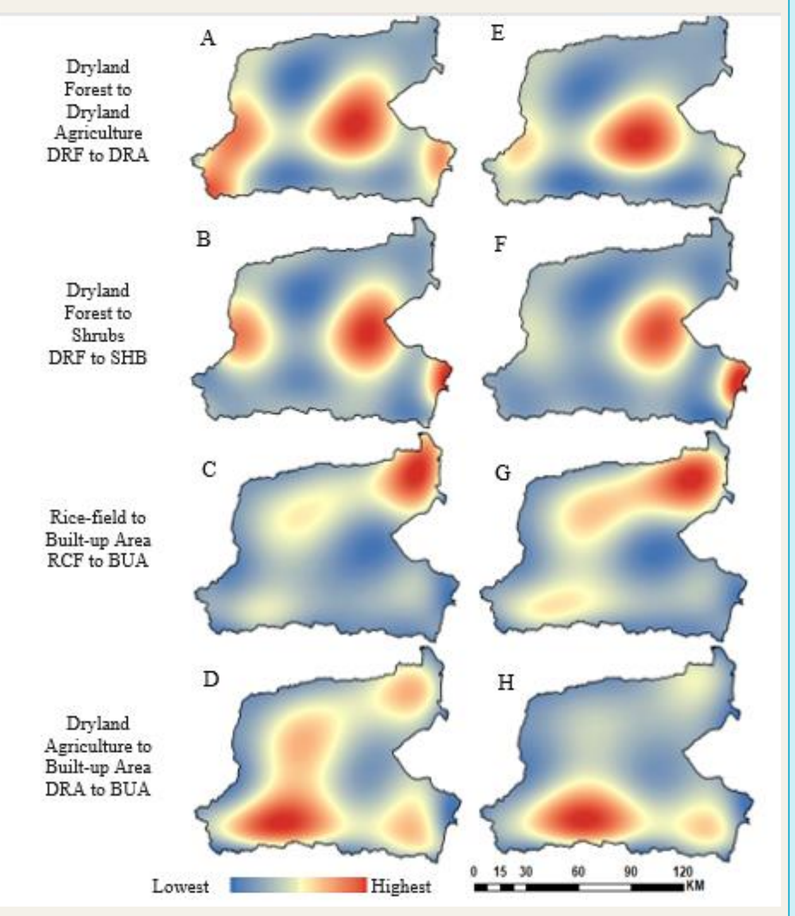

Figure 5. Spatial pattern of major land-use transitions in BRB

Table 2. Agreement matrix between spatial drivers and land-users' based drivers

Variable	Perceived by land-users	Selected by geospatial model	Agreem level
Site quality (scenery)	✓	-	Low
Natural water availability / rainfall variability	✓	✓	**High**
Natural hazards (drought, flood, eruptions)	✓	✓	Low
Soil productivity	✓	-	Low
Elevation	-	✓	Low
Slope	-	✓	Low
Distance to water sources	✓	-	Low
Social empowerment	✓	-	Low
Customary land tenure system	✓	-	Low
Population growth	✓	-	Low
Manpower availability and skills	✓	-	Low
Investment (business)	✓	-	Low
Big housing sales	✓	-	Low
Market price and market access	✓	-	Low
Personal funding for farming	✓	-	Low
Needs of personal huge cash	✓	-	Low
Land-use practice costs	✓	-	Low
Access to economic growth centers	✓	✓	High
Economic incentives (loans, subsidies)	✓	-	Low
Road access and location	✓	✓	**High**
Access to forests and farms	✓	✓	**High**
Public facilities	✓	✓	**High**
Irrigation drainage availability	✓	-	Low
Spatial planning policy & land administration	✓	-	Low
Agricultural technologies	✓	-	Low
Machineries access and availability	✓	-	Low

Spatial pattern of BRB land-use transitions is uneven, with northern BRB has more dynamic in urban development than in southern BRB. Forest loss has concentrated in upland and mid-BRB due to its geographic distribution.

Water-related factor is a driver that has high agreement in spatial modeling and land-user point of view. Socio-economic factors that have high agreement is access to roads, facilities, and land-resources.

Conclusion

Over two decades (1995–2015), the BRB landscape has been marked with reduction in vegetated areas. A tripling in built-up areas signifies a rapidly urbanizing landscape. Major land-use transitions include forest conversion to dryland agriculture and agricultural area conversion to built-up area. The first phase of deforestation in the BRB is agricultural expansion, followed by conversion to built-up areas, which is nearly irreversible. Bio-physical and socio-economic drivers accounted for land-use transitions in BRB. Inconsistencies between spatial drivers and individual drivers might set challenges for integration in spatial and social modeling

Contact Information

Bagus Setiabudi Wiwoho (b.wiwoho@uq.edu.au)