CHAPTER

5

Modeling Effect of Conservation and Livelihood Policies on Community Land Use and Management in Yogyakarta

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5.1 INTRODUCTION

Human population growth is one of the greatest causes of complex problems facing the world, along with climate change, poverty, and resource scarcity (Collodi and M'Cormack, 2009). The urban population has grown more rapidly than rural populations around the world in the last two decades, especially in developing countries. For the first time in 2008, the total urban population (3.4 million) was the same as the number of rural area inhabitants (UN, 2008a). According to current projections, the world's urban population is expected to increase by 3.1 billion people by 2050, whereas the rural population will peak at approximately 3.5 billion in 2019 and subsequently decline (UN, 2008b). Almost all the increase of the urban population is expected to occur in developing countries. Natural growth continues to contribute significantly to the urban population size, which often represented 60% or more of the growth (UN, 2008a).

As the population increases, food production should continuously increase to support global food security. In 2008, approximately 40 million more people suffered from hunger, and the total number reached 963 million (FAO, 2008). According to the United Nations, the world population will increase to approximately 9.1 billion people in the year 2050 (UN, 2008b). Feeding this enormous world population requires the increase of overall food production by approximately 70% from 2005 to 2050, which translates into significant increases in the production of several key commodities. For example, the annual production of cereal would need to grow by nearly 1 billion tons and the production of meat by more than

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200 million tons to a total of 470 million tons by 2050, with 72% from developing countries, which is an increase of 58% (FAO, 2009).

Additionally, loss of prime farmland area due to land conversion is also becoming a major concern. Rapid farmland loss is generally due to the combined effect of rapid economic development, population growth, urbanization, agricultural restructuring, government-stimulated conversion of marginal croplands (to forest and pastures), natural hazards, and land degradation (Braimoh and Onishi, 2007; Cheng and Masser, 2003; Ding, 2003; Firman, 2004; Heilig, 1999; Seto et al., 2002; Verburg et al., 1999; Yang and Li, 2000). Brown (1995) estimated that a decrease in grain production would occur in China during the country's industrialization era. Furthermore, Brown (1995) showed that the loss of agricultural land is greatest in densely populated countries before industrialization, and such countries are rapidly becoming net grain importers. As industry grows, countries lose significant amounts of valuable land for factories, warehouses, roads, parking lots, and houses. As incomes increase, rural farmers leave for cities, which augments food demands (Brown, 1995). Some estimates indicate that there is a production loss of 1–3 million hectares of arable land in developing countries each year to meet the demand for housing, infrastructure, industrial, and recreational land (Doos and Shaw, 1999).

In Indonesia, the National Development Program led to significant economic growth from 1990 to 1998, a period marked by economic deregulation to ease foreign investments and domestic investment to boost the development of nonoil industries and property. As a consequence of the economic structural transformation (from agriculture to nonagricultural) in addition to the change in demographic aspects (rural to urban areas), this process has affected the sustainability of agricultural land (mainly irrigated farmland) (Widjanarko et al., 2004). Meanwhile, loss of farmland has been a national issue since 1994. The Ministry of Agriculture reported that the conversion of agricultural land to residential areas and other urban facilities is greater than 0.15 million hectares per year (DGWLM, 2008).

Due to climate change, the challenge for food security is becoming more complicated. Climate change threatens agricultural production through higher and more fluctuating temperatures, changing patterns of precipitation, and increased frequency of extreme events such as droughts and floods. The effect of population growth, climate change, land degradation, loss of crops and agricultural land on nonfood production, water scarcity, desertification, and urban expansion would result in a 25% decrease in food production in 2050 (Nellemann et al., 2009). Hence, stabilizing global population and protecting the agricultural base, including farmland protection, are prime concerns (Brown, 1995).

Agricultural land protection issues during the industrialization era are raising major dilemmas. Indonesia has become increasingly industrialized, and such increased population and economic growth competes with scarce land for the food supply. Land-use conversion in Java is unavoidable due to high demand for services and jobs; therefore, formulating proper land-use strategies to address such conflicting interests is critical. This study analyzed agricultural land conversion and suggested land-use options for farmland preservation in various contexts.

5.1.1 Land-Use Change in Indonesia

Human population growth and urbanization has significantly impacted spatial planning in Indonesia. Urban development occupied prime agricultural land, notably in the urban fringe area. With a population of over 206 million people in 2003, Indonesia is one of the most highly populated countries in the world after China, India, and the United States. Furthermore, the urban population proportion of Indonesia is still growing rapidly and already reached 30% in 1990 and 42% in 2000 (Firman, 2004). On the basis of the 2010 census, the population of Indonesia was 237.5 million people, and approximately half of them (118 million) live in urban areas (BPS-RI, 2010). This means that urban development is becoming a more pressing problem for the country (Firman, 2011). For this reason, a policy of urban spatial development capable of responding to rapid urbanization is crucial in Indonesia.

In Indonesia, most of the encroachment on agricultural land by urban growth has occurred on Java Island, which is the most populated island, with 58% of the total population of the country in 2010 (BPS-RI, 2010). In Java and Bali, 1.7 million hectares have been converted during the last decade, particularly in the provinces of West, East, and Central Java, which is the most fertile land in Java Island. Because Java Island has the most fertile soil and the highest level of agricultural infrastructure among other islands, farmland loss in the urban fringe area may jeopardize the local, regional, or even national agricultural base of the economy (Yunus, 1990). In 2000, agricultural land in Indonesia was approximately 50 million hectares (ha) or 26% of the total land area. Of the total land area, 54% was in Java and Bali, and approximately 10% of land is still under forest cover. However, forest cover is still the predominant land use in the outer Java and Bali islands, but deforestation is high (Undang, 2003).

Yogyakarta is a province located in the southern part of central Java Island, Indonesia (Fig. 5.1). Land-use change analysis is of extreme interest in this region due to the high dynamics, rapid urbanization, and substantial loss of prime agriculture area (Ritohardoyo, 2001). Land-use change monitored from 2002 to 2006 by the Provincial Board of Planning and Development of Yogyakarta revealed a significant enlargement in the Yogyakarta urban area. This urban development has increasingly encroached on farmland especially rice fields (BAPPEDA-DIY, 2007). Interpretation of a satellite image from 2009 revealed that wet agriculture land and dry agriculture land covered an area of 438.61 and 220.78 km^2, respectively (Partoyo and Shrestha, 2013). Land-use conversion from rice fields to another land-use type is threatening local rice production in Yogyakarta (Syamsiar, 2013). In addition, Yogyakarta has anticipated a transition period toward full implementation of the newly promulgated

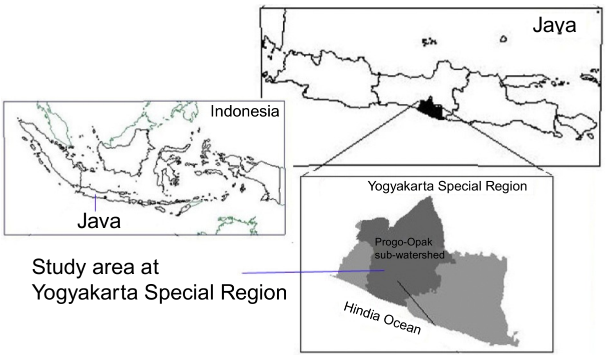

FIG. 5.1 Study area at Yogyakarta.

Indonesian Law No. 41/2009 on farmland protection. This law requires data inventory and supporting regulation to be prepared during the transition period. Geographically, the province is situated between south latitude 7°3′–8°12′ and east longitude 110°00′–110°50′. The province consists of one municipality and four regencies, which are the Yogyakarta municipality, Sleman regency, Bantul regency, KulonProgo regency, and Gunungkidul regency. Dealing with the most land-use change, this study focused on the Progo-Opak subwatershed, which primarily belongs to Yogyakarta municipality, Sleman regency, and Bantul regency. The study area covers approximately 1502 km^2 of land between the altitude of zero in the Bantul alluvial plain bordered by the Hindia Ocean in the south to 2968 m in Mount Merapi in the north. The watershed represents the most urbanized region in the southern part of central Java.

5.1.2 Land Regulation in Indonesia

Indonesian land regulation has developed significantly since the issuance of the Basic Agrarian Law (Undang-Undang Pokok Agraria, UUPA) in 1960. This law is remarkable as a completion of preexisting ordinances, some of which are products of colonial government. The first implication of the law was a land reform program launched in the 1960s with the goal of distributing land in a fair, equitable manner as a source of livelihood for farmers.

UUPA mandated that a certificate should be issued to ensure land ownership. However, this larger program was not very successful in implementation. There are at least five possible reasons for this failure, namely, lack of political will and support, financial shortage, lack of reliable data and information, and weakness in the operating rules and lack of trained human resources (Nasoetion, 2003).

Over the past 42 years (1960–2002), the National Land Agency (BPN) authority only redistributed 885,000 ha of land, less than 2% of the total agricultural land area in the country. This land was distributed to 1.3 million farmer households or only 7% of the total farmer households in the country (Ali, 2006). The agricultural census in 1993 reported that 70% of rural households occupied less than 0.5 ha. The latest agricultural census in 2003 reported that farmer households with land holdings less than 0.5 ha increased from 10.8 million households in 1993 to 13.7 million households in 2003 (BPS-RI, 2004).

The UUPA was developed with the intention to addressing issues related to rural land and, therefore, it neglects urban land problems. However, urban land development is now an emerging issue that must be addressed in light of socioeconomic conditions that have greatly changed. In 1960, the UUPA clearly stated that land has both social and functional values and, therefore, it is not a commodity that can be traded for profit. In this case the UUPA is not able to address the recent trend of land commoditization (Ali, 2006).

In addition, there is much evidence that land ownership has not been protected by land certificate. The ownership is still only registered in a book called Letter C, which is held by the village government. This type of ownership is weaker in law than a land certificate, and it is difficult to transfer. However, several land ownerships have been granted to children because of the inheritance process, but the certificate is still registered under the parents. This is called family ownership. For example, ownership is difficult to transfer to the person who bought the land because the family collectively owns the land. For that purpose, the family should apply to the BPN for the issuance of a new certificate for each family member.

Intention to reimplement land reform was raised later in 2001 and was induced by the House of Representative Decree (TAP MPR) IX/MPR/2001 on land reform and natural resource management. The decree mandated that the President of the Republic of Indonesia serve as the executive government to develop a land reform policy. Land reform policies were then issued as Presidential Decree No. 34/2003 on national land policy. With this decree, the BPN is charged with two tasks to accelerate agrarian reform. First, the draft amendment of the Basic Agrarian Law (UUPA 1960) and the draft of a law about land ownership were prepared. Second, a land information and management system was developed (Ali, 2006).

Currently, agrarian reform is still underway. The essence of agrarian reform is in terms of ownership and control of land redistribution (Winoto, 2005). In 2009, the government redistributed 310,000 ha of land to 17 provinces (Santosa and Idris, 2009). Redistribution of land is part of the two agrarian reform measures by BPN. Another step is to set the political system and land-related law (Winoto, 2010).

After UUPA 1960, several policies and regulations have been developed regarding the utilization of natural resources in Indonesia, but these are fragmented in terms of objectives, orientation, and institution. Not surprisingly, these regulations and policies have been inefficient, inconsistent, and conflicting at times. Several laws and regulations are listed in Table 5.1.

5.1.3 Land-Use Policy Anticipating Farmland Conversion to Nonagricultural Use

The national economic development policy of Indonesia focusing on industrialization has placed pressure on land resources. Land has been exploited for short-term needs and benefits enjoyed by only a small portion of society to support economic development. Economic policies focused on growth have facilitated the allocation of land to large investors and given less access to the people for the acquisition and utilization of land (Firman, 2004; Widjanarko et al., 2004). According to Nasoetion (2003), the causes of this situation were various sectoral laws that overlap or even contradict one another and inconsistencies in implementation. In any circumstance, land development authorities provide the easiest way for investors to obtain land for operation; even by relaxing the requirements for land development permits, if necessary. Consequently, land conversion is not regulated because of the uncontrolled issuance of development permits (Firman, 2000).

Discussion and countermeasures of farmland conversion have been initiated since the 1990s. Several regulations have been established to control farmland conversion and to prevent anticipated conversion of prime farmland to nonagricultural use. However, this implementation has not been effective. There have been many violations of Presidential Decree No. 53/1989, which clearly states that developmental activity should not occur in the preservation and conservation area or on prime and irrigated agricultural land (Firman, 2004). Some regulations related to anticipation of agricultural land conversion are shown in Table 5.2.

TABLE 5.1 Several Laws and Regulations Related to Land Resources in Indonesia

Title	Content
Law 26/2007	Spatial Planning, updated from Law No 24/1992 for the same subject
Law 7/2004	Water Resources, updated from Law No. 11/1974 about Irrigation
Law 3/2002	State Land
Law 41/1999	Forestry, updated from Law No. 5/1967 about Basic Terms of Forestry
Law 23/1997	Environmental Management
Law 4/1992	Housing and Settlement
Law 5/1990	Conservation of natural resources and its ecosystem
Law 5/1960	Basic Agrarian Law
Government Regulation 26/2008	National Spatial Planning, updated from Government Regulation 47/1997 for the same subject
Government Regulation 16/2004	Land Use
Government Regulation 44/2004	Forestry Planning
Government Regulation 68/1998	Area of natural resources preservation and conservation
Presidential Decree 4/2009	Coordinating Board for National Spatial Planning
Presidential Decree 34/2003	National Policy on Land
Presidential Decree 33/1990	Land Use for Industrial Area
Presidential Decree 32/1990	Management of Protected Area
Presidential Instruction 1/1976	Synchronization Task on Agrarian, Forestry, Mining, Transmigration, and Public Work
Regional Regulation	Detailed District/Municipality Land Use Planning
Traditional regulation	Sultan Ground in Province of Yogyakarta Special Region

Source: *Ministry of Public Work, Republic of Indonesia.*

According to Nasoetion (2003), three fundamental constraints were the reason that land conversion control included difficult to implement regulations: (i) a contradictory policy, (ii) the limited scope of the policy, and (iii) the inconsistency of planning. First, the government attempted to ban agricultural land conversion due to contradictory policies, but policies regarding industrial/manufacturing and other nonagricultural sector development encouraged the conversion of agricultural land. Second, the limited scope of the policy implies that regulations were imposed mainly on the companies/legal entities that will occupy land and/or will convert agricultural into nonagricultural land. Meanwhile, conversion of agricultural to nonagricultural land by individuals has not been addressed by these regulations, even though land-use conversion by individuals is estimated to be significant. Third, planning inconsistency was found in the Regional Spatial Plan (RTRW), which was followed by a permit issuance mechanism for the permissible land conversion area. In fact, RTRW involves the conversion of irrigated paddy fields to nonagricultural use. Data from

TABLE 5.2 Several Land Regulations Anticipating Farmland Conversion

No.	Regulations Descriptions	Description
1	Law No.24/1992	Indonesian law ordered development of regional spatial planning should consider irrigated paddy field
2	Presidential Decree No.53/1989	Development of industrial area is prohibited to convert prime agricultural land
3	Presidential Decree No.33/1990	Prohibition of permit issuance for conversion of wetland and irrigated land for development of industrial area
4	SE MNA/KBPN/410-1851/1994	Prevention of conversion of irrigated paddy field to nonagricultural use by development of spatial planning
5	SE MNA/KBPN/410-2261/1994	Location permit should not convert irrigated paddy field
6	SE/KBAPPENAS/5334/MK/9/1994	Prohibition of conversion of irrigated paddy field to nonagriculture use
7	SE MNA/KBPN/5335/MK/9/1994	Spatial plan for district level should not convert irrigated land to non-agricultural use
8	SE MNA/KBPN/5417/MK/10/1994	Land use efficiency in residential development
9	SE MENDAGRI/474/4263/SJ/1994	Preservation of irrigated land to support food self sufficiency
10	SE MNA/KBPN/460-1594/1996	Prevention of wet agricultural land conversion to dry land

Source: *Murniningtyas, E., 2006. Strategy for controlling agricultural land conversion, Jakarta: Directorate of Food and Agriculture, Ministry of National Development Planning – BAPPENAS (in Indonesian); Widjanarko, B.S., Pakpahan, M., Rahardjono, B., Suweken, P., 2004. The agrarian aspect in controlling the conversion of agricultural (paddy field) land. Paper Presented at the National Seminar on Multifunction of Rice Field, Bogor, Indonesia (in Indonesian).*

the Directorate of Land Use of the BPN indicated that not reviewing such spatial planning would result in only about 4.2 million hectares (57.6%) that can remain functional. The remaining area of approximately 3.01 million hectares (42.4%) is threatened by conversion to other uses (Winoto, 2005).

Other weaknesses in the existing legislation are the following: (i) agricultural land protected from the conversion process is based on the physical condition of the land, but the physical condition can be manipulated relatively easily, and land conversion can occur without violating the regulations; (ii) the existing regulations are most often an appeal and are not equipped with clear sanctions for both penalties and determination of the sanctioned party; and (iii) in the event of agricultural land conversion that violates existing regulations, tracing the responsible institutions is difficult because conversion permits are a collective decision by various institutions (Simatupang and Irawan, 2002).

In addition, there are two other strategic factors. First, farmers as landowners and agents in local institutions have not been actively involved in various efforts to control agricultural land conversion. Second, there has been a lack of commitment, coordination system improvements, and competence development of formal institutions in dealing with agricultural land conversion. Some of the abovementioned weaknesses and limitations have caused the existing policy for agricultural land conversion to not directly address critical field components (Iqbal and Sumaryanto, 2007; Simatupang and Irawan, 2002).

In some cases, agricultural land conversion to other uses is a dilemma. Increased population and rapid economic activity growth in some areas require sufficient land for nonagricultural use. However, population growth also requires a bigger food supply, which means that more area is needed for agricultural land, while the total land area is fixed. As a result, there has been intense competition in land use resulting in increased land value (land rent) and that the use of land for agriculture will always be defeated by other uses, such as industry and housing (Nasoetion and Winoto, 1996), although the intrinsic value of farmland, mainly paddy fields, was much higher than its market value (Pakpahan et al., 2005; Sumaryanto and Sudaryanto, 2005).

On the internal side of the agricultural sector, various farm characteristics have not fully supported the implementation of existing agricultural land preservation. The narrowness of the average cultivated land area for a farmer due to the fragmentation caused by the inheritance system has increasingly marginalized farming activities. The narrowness of the land holding resulted in inadequate revenue of the agricultural business activities to cover the needs of daily life and does not encourage the application of new technologies to increase productivity. Instead of the technological applications, the farmland is sold to other users for profit (Murniningtyas, 2006).

5.1.4 Land-Use Policy in Yogyakarta

In the case of the Yogyakarta Special Region (Daerah Istimewa Yogyakarta, DIY), the primary land-use issue is the conflict of interest between urban development and agricultural land preservation. At least three factors are considered to drive urban development. First, high population growth in the urban area significantly increases population density. With denser populations, the environmental quality becomes inadequate to provide good living conditions, and groups of people are motivated to move to other places. Land encroachment has happened because most selected places are suburban or rural areas, which are predominantly agricultural land. In fact, people with a higher level of wealth and educational background prefer to build houses separate from their parents, while economically weak groups typically live with their parent families.

Second, Yogyakarta municipality sprawl is a combination of concentric, ribbon, and frog leap patterns. This has directed the new settlements to grow rapidly and not only along the road or surrounding the city but also in many other locations (Yunus, 2009). The policy of national government called “Perumnas” (Perumahan Nasional, national public housing) aimed at creating suburban residential neighborhoods for lower-middle income was launched in 1974 (Perumnas, 2010), which was designed with well-organized space and good quality construction. However, this policy initiated an urban sprawl because location selection is primarily based on the low cost of land, which is mostly in rural areas. This emerging settlement has accelerated the conversion of surrounding agricultural land into a built-environment to provide supporting services for the new inhabitants.

Lastly, the high settlement demand in Yogyakarta is caused by the preference of people to live in this city. In addition to high demand for student boarding, many people living outside of Yogyakarta bought houses as an investment to live in the city after their retirement (Azhar and Roozanty, 2010). Yogyakarta is the Indonesian city with the longest life expectancy of 73 years compared to the Indonesian average of 67 years (BPS-RI, 2005).

Statistics show that the increased urban development has lasted for nearly four decades since 1970 (Ritohardoyo, 2001). Furthermore, the loss of agricultural land has increasingly threatened food availability. Land-use policies have been applied such that this phenomenon continues to occur unexpectedly.

Anticipating this condition in 1992, the provincial government of DIY formulated a Planning for Provincial Spatial Structure (Rencana Struktur Tata Ruang Propinsi, RSTRP) 1992–2006. This is a policy to develop proper land use and involve sustainable urban development and agricultural land protection. In relation to urban development, the RSTRP provides strategies and rules to develop an improved urban area. In terms of agriculture protection, RSTRP has a strategic role in determining the success of agricultural land protection for two primary reasons. First, RSTRP is a structured spatial plan that arranges and directs the use of whole land, including agricultural land. Secondly, the role of RSTRP is to influence the pattern of agricultural land, particularly the connection with urban planning. Unfortunately, this policy was not effective (Irham, 1993), as evidenced by scattered urban development, unprecedented urban expansion, and high loss of prime agricultural land.

Furthermore, the policy did not effectively protect the land, and previous analysis identified several weaknesses (Irham, 1993). First, RSTRP is a too broad policy. The guideline was aimed at the provincial level only. The detailed planning for the regency/municipal level has not yet been formulated. In this case, the policies seem to be vague, which in turn confuses local officials. Second, RSTRP had no flexibility to accommodate changes in socioeconomic conditions. Parts of the guideline were no longer applicable for a certain area, and no evaluation could be performed immediately. Third, monitoring and control was difficult to conduct. The document can only be comprehended by provincial-level officials, while the land-use conversion occurs at the regency level. Fourth, the BPN is in charge of managing land-use issues and experienced difficulties applying the RSTRP to these problems. The RSTRP should coordinate many related department/institutions, particularly the office of agriculture, office of public work, and Board of Local Development and Planning (Badan Perencanaan Pembangunan Daerah, BAPPEDA). Successful coordination is a common constraint in developing bureaucracy, including the government of the Province of Yogyakarta Special Region. Fifth, there was inconsistency between RSTRP and the spatial planning of regencies/municipalities because they were formulated separately and did not refer each other. Sixth, there was no agricultural zoning ordinance in the RSTRP and no clear legal basis for BPN to prohibit any nonagricultural development proposal on agricultural lands.

Regarding agricultural regulation, Indonesia initiated national laws related to agriculture in 1992 after the issuance of Law No. 12/1992 on the crop cultivation system. This law assures the rice self-sufficiency level, which was reached in 1984, and supersedes all predecessors, including more than 10 ordinances issued by the colonial government. In the following year, many supporting regulations were created to implement the law for various pesticides and fertilizers but not for related land-use issues.

The escalating conflict of interest on land utilization between sectors/subsectors forced the government to renew the outdated regulation by issuing Law No. 26/2007 on spatial planning. This new law reaffirmed the mandate of Law No. 12/1992 on the crop cultivation system to publish legislation for the protection of agricultural land. Beginning in 2007 with the draft entitled Permanent Agricultural Land Regulation. the document has undergone much revision based on objections and criticisms. Finally, the approved draft has been issued as Law No. 41/2009 for the protection of land for sustainable food crop farming on Oct. 14, 2009. This latest law is the primary reference related to agricultural land conversion issues, which refers to the law, the Government of Yogyakarta Special Region has issued Provincial Regulation No. 10/2011 and several supported Regency Regulations to sustain agriculture land in the area.

Based on this analysis, several gaps were identified that resulted in land-use policy failure, particularly inhibiting the encroachment of agricultural land by settlement development. These weaknesses include the lack of applicable regulations, weakness of law enforcement, and lack of a supporting policy to encourage farmers to keep their agricultural land. This example demonstrates that agricultural land conversion involves three stakeholders, which are the government as regulator, the farmer as actor in agricultural land use, and the housing developer/individual as demander/user.

5.1.5 Driving Factors of Land-Use Change in Yogyakarta

Land-use changes are usually modeled based on the biophysical and socioeconomic variables chosen to serve as driving forces (Turner-II et al., 1993). Driving forces are usually divided into three groups: socioeconomic drivers, biophysical drivers, and associated land management variables (Turner-II et al., 1995). Although most biophysical factors do not drive land-use changes directly, these factors can cause changes in land cover (eg, through climate change) and affect decisions of land-use allocation (eg, soil quality). On another scale of analysis, the dominant driving factor in land-use systems could be different. This can be a local policy or the presence of small areas of ecological value at the local level, while the distance to ports, markets, or airports may be the primary determinant of land-use patterns at the regional level (Turner-II et al., 1995).

Driving forces are generally considered to be exogenous to the land-use system to facilitate modeling (Verburg et al., 2004). However, in some cases this assumption hampers the proper description of the land-use system. For example, population pressure is often regarded as an important driver of deforestation. Pfaff (1999) noted that the population is not always endogenous to forest conversion depending on the local issue context. If increased population is facilitated by forest clearing, involving population as an exogenous driver of land-use change would produce a biased estimate and lead to a misleading policy conclusion. If the population is collinear to the forest conversion process, then the estimates would be unbiased but inefficient, leading to a potential false interpretation of the significance of variables in explaining deforestation (Verburg et al., 2004). Another example of endogeneity of driving forces in land-use study is given by Irwin and Geoghegan (2001).

The choice of driving forces is highly dependent on simplifications and theoretical and behavioral assumptions in land-use modeling. In the economic approach, most economic models of land-use change are related to the land rent theories of Von Thunen and Ricardo (Nelson, 2002). In the simplest form (ie, the monocentric model), the distance to the urban center is the most important driving variable. Other models, such as the hedonic model, that try to explain land values, combine variables that measure the distance to the urban center and specific location features of the land parcel (Bockstael, 1996).

The temporal analysis scale is important for determining which driver is endogenous to the model. In economic models of land-use change, a function of supply and demand is the driving force of land-use change. Price can be considered exogenous to changes in land use in the short term, but it is endogenous at longer timescales (Doygun, 2009; Verburg et al., 2004).

Summarizing several reported case studies (Lambin et al., 2003; Pfaff, 1999; Serneels and Lambin, 2001), land-use change is affected by a combination of factors, including biophysical, economic, technological, demographic, institutional, and cultural/social factors.

In the case of Yogyakarta, land-use change was related to biophysical, socioeconomic, and policy factors. With respect to agricultural land conversion, evidence of land-use change to built-up land mostly occurred at locations far from the district's capital city, close to the road, low in altitude, and low in population (Partoyo, 2010). Agricultural land conversion is expected to continue. Recently, agricultural land conversion to a built-up area occurred in areas with an irrigation facility and highly suitable for rice cultivation (Tarigan, 2013).

Regarding socioeconomic factors, agricultural land conversion was related to decisions and perceptions about farmland conversion. The study of Partoyo (2011) revealed that the household decision to convert farmland was significantly related to revenue earned from farming activity, socioeconomic background of the household, farming sustainability, access to agricultural information, perception about farmland protection, and land tenure. The possibility of the household deciding on wet agricultural land conversion will be higher for a household with higher revenue from farming activity; that is, large land-holding farmers, higher socioeconomic status of the household, less access to information on land-related regulation, less possibility to sustain farming activity, negative perceptions of farmland protection, and secure land tenure (Partoyo, 2010; Partoyo and Shrestha, 2013).

Related to policy, several land-related regulations have been launched, but without effective enforcement. Regulations related to land have not been widely recognized by people, including the prohibition of prime agricultural land conversion.

A household survey in the study area (Partoyo, 2011) indicated that farmers' livelihoods were vulnerable to decisions on agricultural land conversion. The average surveyed family size is typically small with three members. Although farming is a major occupation, income from farming activity contributes only 54% of household expenditures. Nevertheless, these households are not categorized as poor, and the average per capita income in the study area is slightly higher than the national poverty limit. People in the area seek minor occupations to obtain additional income for financial betterment.

Typically, farmer households in the study area have very small agricultural land (on average 0.24 ha), which is not feasible as a primary source of household income. The four most common farming problems were lack of financial capital, low price of farm products, high price of fertilizer, and marginally small profit. When surveyed about farming revitalization, the four most significant requests were subsidized inputs, financial capital access, farming insurance, and upgraded farming technology. This result implied that technology was not a major problem, but financial factors were unmanageable (Partoyo, 2011).

Regarding land conservation, the respondents agree that sustaining viable crop cultivation and preserve land resources is important. Several conservation measures are practiced with farming activity, although almost two-thirds do not recognize regulations governing this issue by the public authority. For agricultural land conversion, approximately one-third were aware of one or two regulations that addressed this issue. Regulation to prevent prime agricultural land conversion to nonagricultural use already existed but was poorly enforced. Households have their own reasons other than regulation enforcement to sustain agricultural land, such as recognizing the agricultural land as a family inheritance or as valued household assets. However, 37% of household respondents that experienced agricultural land conversion indicated the reason was monetary needs for consumptive use and financial capital (Partoyo, 2011).

Regarding access to information, households are commonly informed mainly during farmer group meetings by colleagues, agricultural extension officers, or other government officials. Farmer group meetings are effective forums that can enhance discussions of new agricultural technology and government regulations.

Although current rice cultivation in the existing paddy field is sufficient to fulfill the food demand, farmland zoning is desirable for identifying the prime agricultural land to preserve a reliable food production system. Due to land-use change, wet agricultural land situated on the high-potential land suffered a 1.14 km^2 loss per annum. In 2009, 20% of high-potential land in the study area was occupied by built-up land use. Zoning of the study area based on land potential into four land classes: high, moderate, low, and no potential, which is required to develop spatial policy on farmland protection. Conversion of high-potential land should be controlled to prevent potential loss of rice production. Farmland with high potential should be preserved.

5.2 LAND-USE CHANGE MODELING

Modeling of land-use change allows for analysis of the causes and consequences of land-use change to better understand the function of the land-use system and to support land-use planning and policy. The model aims to simulate the function of land-use systems and to conduct spatially explicit simulation of land-use patterns in the future (Verburg et al., 2004).

The models are designed for running several scenarios for policy choices. Scenarios should not be confused with forecasts because these do not allow for prediction but rather the exploration of technical options based on explicit assumptions for a set of goals. The strength and weakness of each will be demonstrated by running scenarios. Land-use models may help to make potential choices more visible. Then, policy makers and land users can decide more easily on explicit choices.

Regarding selection of variables for the model, there has been advanced development of the inductive approach involving empirical selection of many suspected variables until deductive selection based on a firm theoretical background (Overmars et al., 2007). The simulation was more visually depicted under the contribution of geographical information systems (GIS) and the remote sensing technique (Irwin and Geoghegan, 2001; Schweik and Thomas, 2002). Land-use change simulation has also been developed to include dynamic factors in the scenario to facilitate top-down and bottom-up approaches (Xiang and Clarke, 2003). This allows for the involvement of socioeconomic variables, which are usually not spatial in nature, instead of biophysical variables. Many land-use modeling scholars have been more interested in the process of land-use change and not only the pattern of change (Bakker and van Doorn, 2009; Nagendra et al., 2004). The combination of remote sensing and household data became more popular after “socializing the pixel” and “pixelizing the social” were described by many scholars (Geogeghan et al., 1998). Therefore, land-use change modeling resulted in a more acceptable output for the decision maker and stakeholder to develop land-related policy.

A model should be developed that integrates disciplinary approaches and models studying urban and rural land-use change to better support the analysis of land-use dynamics and policy formulation (Verburg et al., 2004).

Regarding the involvement of broad drivers of change, a new concept of Land Use and Cover Change (LUCC) has been developed to account for the interaction between biophysical characteristics of land and socioeconomic conditions. Landowners or users as well as institutions are considered agents for decision-making processes that influence the land-use/land-cover change (Rajan and Shibasaki, 1998).

The decade since the initiation of the LUCC project in 1995 has witnessed considerable advances in the field of LUCC modeling. During this period, the combined use of simulation models, expert systems, GIS, various types of databases and multiple goal planning techniques has allowed for technical land-use options to be formulated in a more precise and varied way.

Reviews have characterized and classified land-use models (Verburg et al., 2004), a model based on economic theory (Bockstael, 1996), a model for deforestation (Kaimowitz and Angelsen, 1998; Lambin, 1997), integrated urban models (Hilferink and Rietveld, 1999), and agricultural intensification models (Lambin et al., 2000).

A wide range of techniques are available, and each has its own strengths and limitations. Several techniques, including microeconomic (Caruso et al., 2005) and multiagent-based simulation (Brown et al., 2005), deal with land-use change as a consequence of socioeconomic conditions. The increasing concern among LUCC scholars about land-use models that are spatially explicit has resulted in several approaches, such as logistic regression (Overmars and Verburg, 2005), neural networks (Pijanowski et al., 2005), cellular automata (Jantz and Goetz, 2005), and Markov chains (Pontius and Malanson, 2005).

Cellular automata are frequently used in land-use modeling with spatially explicit approaches. Land-use change is simulated as a function of neighborhood land use and a set of driving-factor relationships (Balzter, 2000). Neighborhood functions and transition rules are specified either based on user expert knowledge or empirical relationships between land use and driving factors (Pontius et al., 2001).

The Dyna-CLUE model (Dynamic Conversion of Land Use and Its Effects) (Verburg and Overmars, 2009) is based on spatial allocation of demands for different land-use types to individual grid cells. This model has the advantage of allocating land use simultaneously based on the highest possibility among competitive land-use types based on prescribed scenarios. Simulation will be shown in a spatially explicit result to visualize the projected effect of land-use policy, which provides a wide-scale of simulation based on the analysis level, even until the watershed level with the highest accuracy, depending on the available data.

There is an adapted version of the CLUE-s model (Castella et al., 2007; Verburg et al., 2002). The predecessor CLUE has been used and validated in multiple case studies of land-use change in many regions including Europe (Britz et al., 2011), Costa Rica (Veldkamp and Fresco, 1996), Ecuador, Central America, Honduras, China (Luo et al., 2010), Java-Indonesia (Verburg et al., 1999), Sibuyan Island (Philippines) and Malaysia (Verburg et al., 2002), and Vietnam (Castella and Verburg, 2007).

Dyna-CLUE has been successfully implemented in Thailand, as Trisurat et al. (2010) used the model to project land use change from 2002 to 2050 due to deforestation. Improved from the former version of CLUE, Dyna-CLUE combines more dynamic modeling and empirical quantification of the relations between land use and its driving factors. Probability for each location to be changed is estimated on the basis of actual land use and the competitiveness of different types of land use. Scenarios can be prescribed to evaluate different land-use change situations cause by differences in land-use requirements and spatial policies (Verburg and Overmars, 2009).

This study applied the Dyna-CLUE platform for modeling the effect of land-use policy on the future land use of the study area. The procedures applied are described as follows.

5.2.1 Preparation of Land-Use Base Map

We derived a base map of land use of the study area from a Landsat ETM+ image acquired in 2004 and a reference map of land use from ASTER Terralook images acquired in 2009. The standard procedure for image preparation was done prior to image interpretation. Using maximum likelihood classification, we classified seven classes of land use: wet agriculture land (WetA), dry agriculture land (DryA), mixed garden (MixG), high-density built-up land (HiBu), low-density built-up land (LoBu), forest, and miscellaneous.

5.2.2 Developing Inputs for Land-Use Modeling

Four inputs were prepared for land allocation procedure in this land-use modeling: logistic regression model, land demand, conversion elasticity index, and conversion sequence matrix.

5.2.2.1 Logistic Regression Model

The regression models link the functional relationship between land-use type and location factors. Location factors were variables contributing to the probability of certain land-use types existing at certain locations. In this study, we used 14 location factors as follows: Elevation (=E), Slope (=S), Distance to main road (=R), Distance to capital city of district (=D), Distance to capital city of regency (=Rg), Distance to capital city of province (=P), Land suitability for rice (=Rs), Irrigation support (=I), Population density (=Pd), Land property right (=Pr), Land utilization right (=U), Land owned by village (=V), Land owned by state (=St), and Land of SG/PAG (=SG). Based on land-use maps and other GIS data prepared, we have developed binary logistic regression models for each land-use type as follows (Partoyo, 2012):

$$\mathrm{HiBu} = 0.84 + 0.004\mathrm{E} - 0.13\mathrm{S} - 0.0005\mathrm{R} - 0.0001\mathrm{D} + 0.0001\mathrm{Rg} - 0.0003\mathrm{P} + 0.00001\mathrm{Pd} - 0.17\mathrm{Pr} - 0.55\mathrm{U} + 0.50\mathrm{SG} + 0.58\mathrm{Rs} + 1.03\mathrm{I}$$

$$\mathrm{LoBu} = -3.78 - 0.002\mathrm{E} + 0.01\mathrm{S} - 0.00008\mathrm{D} - 0.00006\mathrm{Rg} + 0.0001\mathrm{P} + 1.18\mathrm{U} + 0.54\mathrm{St} - 0.32\mathrm{Rs} - 0.26\mathrm{I}$$

$$\mathrm{WetA} = -1.73 - 0.003\mathrm{E} - 0.038\mathrm{S} + 0.00008\mathrm{R} + 0.00008\mathrm{D} - 0.00006\mathrm{R} + 0.00009\mathrm{P} - 0.000004\mathrm{Pd} + 0.971\mathrm{U} + 0.366\mathrm{St} - 0.852\mathrm{Rs} - 1.236\mathrm{I}$$

$$\mathrm{DryA} = -5.57 - 0.002\mathrm{E} + 0.098\mathrm{S} + 0.0002\mathrm{R} + 0.0002\mathrm{D} - 0.00005\mathrm{R} + 0.00007\mathrm{P} - 0.00001\mathrm{Pd} + 1.807\mathrm{U} + 1.311\mathrm{St} - 0.205\mathrm{I}$$

$$\mathrm{MixG} = -6.82 + 0.034\mathrm{S} + 0.0002\mathrm{R} - 0.00007\mathrm{D} - 0.00006\mathrm{R} + 0.0001\mathrm{P} + 2.238\mathrm{U} + 0.721\mathrm{St} + 0.165\mathrm{I}$$

$$\mathrm{Forest} = -6.71 + 0.006\mathrm{E} - 0.221\mathrm{S} - 0.0003\mathrm{R} + 0.0001\mathrm{D} - 0.0001\mathrm{R} + 0.0002\mathrm{P} - 0.0001\mathrm{Pd} + 1.596\mathrm{St} + 3.111\mathrm{I}$$

Logistic regression models were calibrated using relative operating characteristics (ROC) value and validated by running the model to project land use from 2004 to 2009 using prescribed input and parameters under an ongoing trend scenario. A simulated land-use map then was compared to a reference land-use map from 2009.

5.2.2.2 *Land Demand*

Land demand declared areas that will be occupied by each land-use type. The area was determined regarding prescribed scenarios of land-use change and calculated for every year until the end of the simulation year.

For this study, land demand was prepared under three scenarios. The scenarios were prescribed considering the implication of farmland loss to rice production, food security and food self-sufficiency, as well as protection of the landscape for better environment. The first scenario was intended to project future land use if change followed the ongoing trend. The calculated land demand was based on empirical data derived from the satellite interpretation and statistical data. The first scenario is called "business as usual." The second scenario was developed to explore the impact of land-use policy on future land use. It used a similar trend of land-use change as the first scenario, but applied farmland protection as spatial policy. This scenario is called the "farmland protection" scenario. The third scenario was prepared to provide enough paddy field area for 400 km^2 by 2030. This area was predicted based on the rate of rice demand and paddy field productivity. The rate of change for each land-use type was determined for the minimum area of farmland required. This scenario is called the "minimum required farmland" scenario. Table 5.3 describes details of the three scenarios.

5.2.2.3 *Spatial Policy*

For some scenarios, areas of land-use change restriction can be defined because of spatial policies, such as the preservation area or protected area. In this study, Merapi National Park and/or the high suitable land for rice were considered a restricted area (Table 5.3).

TABLE 5.3 Characteristics of Land Demand Scenarios for 2030

	Scenario 1: Business as Usual	**Scenario 2: Farmland Protection**	**Scenario 3: Minimum Required Farmland**
Projected land use (2030)	Follows the trend of existing conversion rate (high density built-up, +2.7%; low density built-up, +1.8%; wet agriculture, −0.4%; dry agriculture, −1.2%; mixed garden, −1.0%; forest, −0.7%)	Follows the trend of existing conversion rate (same as Scenario 1)	At minimum 400 km^2 (high density built up, +2.6%; low density built up, +1.8%; wet agriculture, −0.3%; dry agriculture, −1.2%; mixed garden, −0.9%; forest, −1.0%)
Spatial policy	No land conversion allowed in Merapi National Park	No land conversion allowed in Merapi National Park, and in irrigated area with a high land suitability class for rice	No land conversion allowed in Merapi National Park and limited farmland conversion as allowed

5.2.2.4 Conversion Elasticity Index

The conversion elasticity is related to reversibility of land-use changes. This factor is based on expert judgment, ranging from 0 (easy conversion) to 1 (irreversible change). We applied an index of 1 for built-up land, forest, and miscellaneous, instead of wet agriculture land, dry agriculture land, and mixed garden with an index of 0.2, 0.2, and 0.8, respectively.

5.2.2.5 Conversion Sequence Matrix

The conversions that are possible and impossible are specified in a land-use conversion matrix. For each land-use type it is indicated what the land-use type can be converted to during the next time step. Value "1" means land-use conversion possible to take place, while "0" means not possible.

5.2.3 Model Calibration and Validation

Calibration of the predicted land use by the model was done based on the ROC value. The spatial distributions of the allocated land-use types are explained moderately to well by the selected location factors, as indicated by the ROC values that ranged from 0.76 to 0.99. The lowest ROC of low-density built-up land (0.76) is caused by a wide spreading of location of this land-use type in the study area. The high ROC value of high-density built-up land implies an accurate prediction of the location of high-density built-up area. Based on these good ROC values, it means that a model of all land-use types can be implemented in the Dyna-CLUE framework.

Validation of the model was conducted either by visual or statistical methods to compare projected map and reference map year 2009. Under visual examination, both of these maps look similar. High-density built-up land clearly shows similar extent and pattern (Fig. 5.2A and B). Some high-density built-up areas that can be tracked have been developed along the main roads. Wet agriculture land, mixed garden, and forest are also spread in a similar pattern. This good conformity implies the validity of the Dyna-CLUE model for simulating future land-use change in the study area.

Furthermore, a statistical approach was performed to validate the model. We calculated ROC for each land-use type between the projected map and the reference map. The ROC answers on how well the projected map matches with the location map showed on the reference map (Pontius and Schneider, 2001). ROC of 0.5 indicates conformity equivalent to random chance, when the grid cells are hard to classify. ROC of 1 indicates perfect conformity (Pontius and Chen, 2006).

The analysis of ROC resulted in a value of all land-use type ranging between 0.54 and 0.83. The lowest ROC value (0.54) evidences a slightly better conformity of low-density built-up with random locations. The higher ROC of all other land-use types implies that, as a whole, the model projects a valid future land-use map. Based on ROC value, the predictions have better accuracy, respectively, for high-density built-up, forest, mixed garden, wet agriculture land, dry agriculture land, and low-density built-up.

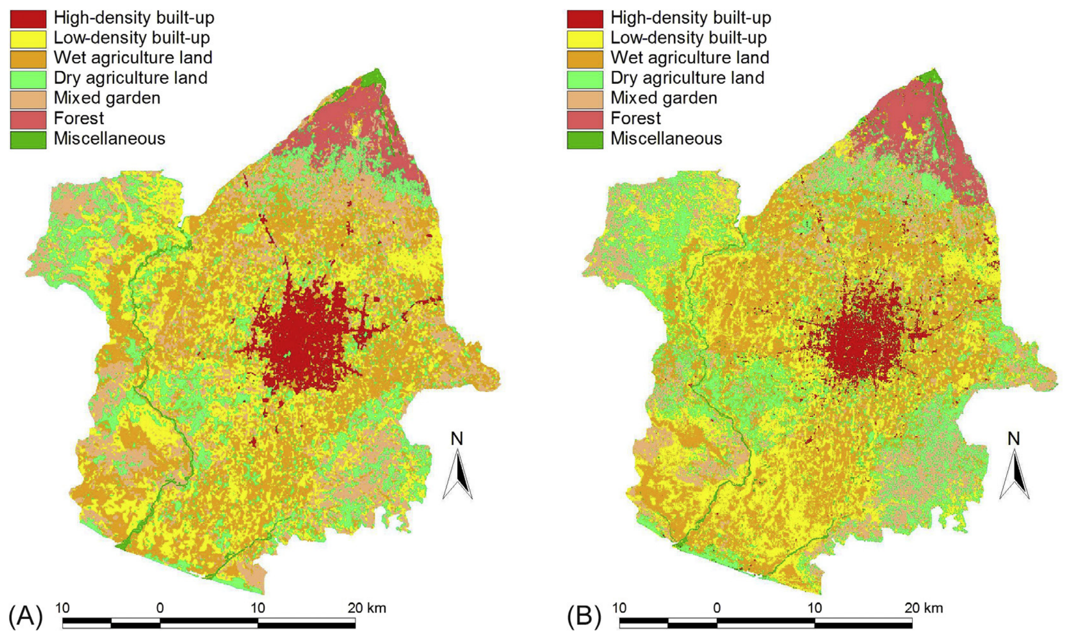

FIG. 5.2 Land-use map: (A) Reference map 2009; (B) Projected map 2009. *Adapted from Partoyo, 2012. Application of spatial modeling for simulating land use conversion to support sustainable agricultural land planning. Proceedings of National Seminar on Agriculture and Fisheries Research, Year 2012. Yogyakarta, 15 September 2012. Faculty of Agriculture Gadjah Mada University. pp. 575–582, ISBN: 978-979-8678-25-7 (in Indonesian).*

5.3 LAND-USE PROJECTION BY 2030

Regarding the satisfied calibration and validation result of the model, we proceeded to use the model to project land use by 2030.

Under scenario 1, simulation resulted in the expansion of the urban area. Both high-density and low-density built-up land expanded to the west instead of northeast and southeast as observed between the reference maps in 2009 (Fig. 5.2A) and 2030 (Fig. 5.3A). It is also shown clearly that some mixed garden and dry agriculture land have been changed into low-density built-up land in the southwest part.

Under scenario 2, urban sprawl is not as much expanded as scenario 1. Increased high-density built-up land mostly occurred within the municipality boundary. This development resulted in a massive area of high-density built-up. It implies that preventing conversion of high-potential agriculture land has hindered urban sprawl from occupying the surrounding area.

Actually both scenarios 1 and 2 allocated a similar area of each land-use type as both assume the same land demand. However, implementation of farmland protection policy in scenario 2 clearly resulted in a spatially different pattern of land use. The projected map proves that land policy governs the pattern of land-use change.

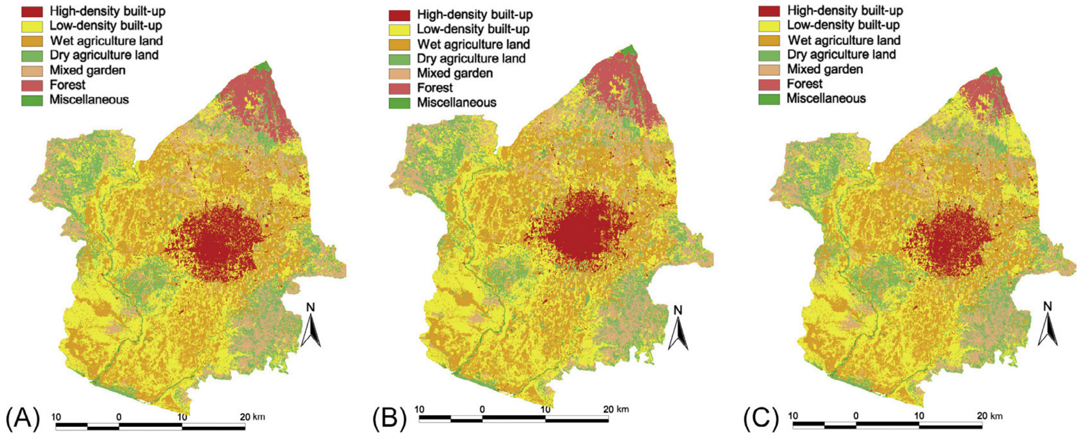

FIG. 5.3 Projected land-use map year 2030 based on the three scenarios. (A) Projected map: scenario 1; (B) Projected map: scenario 2; (C) Projected map: scenario 3.

In term of farmland preservation objective, scenario 2, is successful to preventing high-potential agriculture land conversion against urban sprawl. However, under the ongoing trend of land-use change, both scenarios allocated area for wet agriculture land as only 38,919 km^2, which is less than the area required as 400 km^2 by 2030. This result implies that additional land policy is needed to ensure a sufficient area of land is available for agricultural development. For scenario 3, an area of 400 km^2 was projected for the wet agricultural land. The urban area of scenario 3 (Fig. 5.3C) will be similar in shape to scenario 1 (Fig. 5.3A), but with the former having less massive distribution of high-density built-up land (Fig. 5.3B). The National Park of Merapi Mountain will be preserved from land-use conversion but not the surrounding forest and shrubs, which are converted into low-density built-up land or dry agricultural land.

When comparing the results of all scenarios, scenario 2 yields the most acceptable result. In terms of farmland preservation, this scenario resulted in wet agricultural land that was prevented from becoming urban sprawl. Both scenarios 1 and 2 allocated a similar area for each land-use type as both assume the same land demand. However, implementation of farmland protection in scenario 2 clearly resulted in a spatially different pattern of land use.

Therefore, allocation of adequate farmland area remains a concern because scenario 1 and 2 failed to preserve at least 400 km^2 of wet agricultural land. This result suggests that the current trend of farmland conversion is high and should not continue. Furthermore, future built-up land should not be allowed to occupy wet agricultural land.

This model facilitates incorporating of any additional policy inputs of the study area provided that all other location factors and assumptions remained unchanged and valid.

5.3.1 Proposed Policy

In relation to food availability and land conservation issues, increased land demand for nonagricultural use and high rates of farmland conversion are very threatening. Accordingly, combined land-use options should be implemented to control land-use change and to manage the remaining farmland with appropriate land use.

First, control of land-use change should aim to maintain enough farmland area by reducing farmland conversion. Approaches to decrease farmland conversion include promoting farmer households to not convert their farmland and reducing nonagricultural land demands to avoid competition with farmland.

In addition to enforcing legal sanctions, strategies to empower farmers might be more effective to persuade households to sustain their farming activity. As summarized in Fig. 5.4, the topmost incentives proposed by farmer household to revive their farming activity were subsidized farming inputs, better financial capital access, guaranteed income from farming activity, high-yielding farming technology, and reduced land tax. Therefore, strategies providing those incentives will effectively sustain farming activity, which will result in the maintenance of farmland.

To reduce land demand for nonagricultural use and particularly in built-up areas, strategies for developing building that require less land will be beneficial, such as residential houses. Zoning for residential or industrial areas will also be a useful strategy to suppress competition with agricultural land use. Robust spatial policy will be required to regulate zoning for urban development, including high-density built-up area.

There is projected to be a lack of available wet agricultural land in 2030, and strategies to better manage existing farmland will be useful to secure food production and to conserve environmental functioning. Increasing land productivity is an obligatory strategy to produce sufficient food within the reduced farmland area. High-yielding varieties of rice and related farming technology are required components. The pressure of high rice demand might also be managed through more diversified staple food sources. Food crops other than rice, such as cassava, sweet potatoes, and taro, can be grown on nonirrigated farmland. Therefore, food availability can be secured as rice field area decreases.

Based on the projection result, there will be a lack of wet agricultural land for rice field available in the study area by 2030. To secure food production, land demand for built-up area must be suppressed and not compete with agricultural land. If agricultural land is reduced, food production will be insufficient without increasing land productivity or reducing dependence on rice as the staple food.

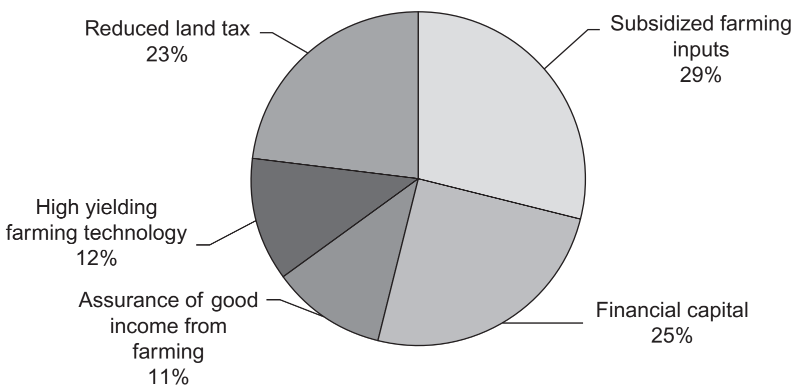

FIG. 5.4 Incentives proposed by households for sustaining viable farming activity. *From Partoyo, 2011. Land Use Options and Strategies for Food Availability in Yogyakarta, Indonesia. Unpublished PhD Dissertation, Asian Institute of Technology, Thailand.*

With the assumption of constant productivity and based on the scenarios tested, protection of wet agricultural land against conversion is necessary. High-potential land must be prioritized for protection. However, any policy should be accompanied to control land demand for agricultural or nonagricultural use.

As concluded above, farmers' decision making is affected by several factors that encourage farmers to convert agricultural land to other uses, and it is important to empower farmers in providing higher revenue from farming activities that will help discourage further conversion of wet agricultural land.

5.4 SUMMARY

Yogyakarta has experienced significant land-use change in the past. The major land-use change includes a decrease of wet agricultural land and dry agricultural land, and an increase of high-density built-up land and low-density built-up land. Urban development has expanded for low- and high-density built-up areas combined by nearly fourfold between 1992 and 2009. Urban sprawl occurred in the former low-density built-up areas and agricultural land around the municipality area. At least 14% of the high-density built-up land in 2009 was converted from former high-potential land for rice cultivation.

Projections of future land use by 2030 indicated that under the ongoing trend of land demand, land conversion will reduce wet agricultural land to be less than the required area (400 km^2). Meanwhile, under the scenario of farmland protection, all high-potential land will be secured from conversion, but still less area will be available for wet agricultural land. With the scenario of providing agricultural area of at least 400 km^2, it needs to reduce land occupation for high-density built-up upon wet agricultural land by 0.1% per year.

Farmland loss due to land conversion has implications for rice production, food security, as well as food self-sufficiency. Meanwhile, land conversion is unavoidable due to higher demand for services and jobs. Spatial modeling figured out what will be the land-use map in the future. As resulted from the simulation, future land-use projections for 2030 indicate that policies on farmland protection and urban development are necessary. It should be coupled with the objective to preserve productive farmland and develop urban expansion in less important farmland so that the land-use change will be controlled to maintain the productive function of farmland and nonagricultural function of other land uses.

The spatially explicit projection methods like Dyna-CLUE give a spatial view of the simulation under different scenarios. Such a projected pattern makes possible an assessment of spatial impact due to different applied scenarios being done in relation to land-use development. As the scenario can be dynamically adjusted considering the recent situation and updated available data, this simulation method can be tailored following any newer prescribed land-use policy.

Factors that drive land-use change, particularly agricultural land conversion to nonagricultural land use, are distance to city, distance to road, population density, elevation, terrain slope, irrigation availability, land tenure, and land suitability for rice cultivation. In relation to factors affecting household decision to convert farmland, six factors, namely, revenue from farming activity, socioeconomic status of household, access to land-related regulation, sustainability of household farming, perception about farmland protection, and land tenure were found to affect decision making.

Irrigation plays an important role to increase rice cultivation intensity, thus implying higher potential to increase production. Considering combined irrigation availability and land suitability as criteria, only 22% of the study area falls into the high-potential class, which calls for immediate protection of these areas. Given the land area of 400 km^2 needed to reserve for rice cultivation by 2030, as per a projection of the Provincial Agricultural Agency, this study showed that the area of wet agricultural land will be less than the required area of 400 km^2. Under the farmland protection scenario in this study, even after preserving all high-potential land from conversion, the availability of wet agricultural land remains below the requirement.

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