Land evaluation for peri-urban agriculture using analytical hierarchical process and geographic information system techniques: A case study of Hanoi

著者	Thapa Rajesh Bahadur, Murayama Yuji
journal or publication title	Land use policy
volume	25
number	2
page range	225-239
year	2008-04
権利	(C) 2007 Elsevier Ltd.
URL	http://hdl.handle.net/2241/102257

doi: 10.1016/j.landusepol.2007.06.004

Land evaluation for peri-urban agriculture using analytical hierarchical process and geographic information system techniques: A case study of Hanoi

Rajesh Bahadur Thapa, Yuji Murayama

Geoenvironmental Science, Graduate School of Life and Environmental Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8572, Japan

Corresponding author. Tel.: +8129 853 5694; fax: +8129 851 6879.
E-mail addresses: thaparb@yahoo.com (R.B. Thapa), mura@atm.geo.tsukuba.ac.jp (Y. Murayama). Tel./fax: +8129 853 4211

Abstract

This paper presents an integrated technique of AHP and GIS to evaluate the land for peri-urban agriculture. Hanoi province, Vietnam was selected for the case study. Transformation of conventional agriculture to modern cash crops is the current trend in peri-urban Hanoi. A field survey with focused group discussions was conducted. Based on field survey data analysis, soil, land use, water resources, road network and market were chosen as major factors affecting the peri-urban agriculture. A map of each factor with different logical criteria was prepared. The Analytical Hierarchical Process (AHP) method was applied to identify the priority weight of each factor. Five spatial layers with their corresponding weights were linearly combined to prepare the suitability map. The map was further scaled as High suitable, Medium suitable, Low suitable and Unsuitable land for the peri-urban agriculture. This empirical scenario provides a cost effective, rapid land evaluation framework which may help policy makers, urban and regional planners and researchers working in developing countries.

Keywords: peri-urban agriculture, urban fringe, land evaluation, AHP method, suitability assessment, Hanoi.

Introduction

Peri-urban zones are considered as a transitional zone between urban and rural areas. The habitat of a diversity of populations, the heterogeneity of land uses, the morphological conditions and densities of the built areas, the complex functional relations and the changing social structure are some of the characteristics of the peri-urban area (Adell, 1999; Allen, 2001; Tacoli, 2001). These characteristics of peri-urban area will be transformed to the urban system. The transformation process decreases the cultivated area because of significant trend of city sprawl to urban and peri-urban agricultural areas (Zeng et al, 2005). Urban expansion is governed by geographic and socio-economic factors such as population growth, policy and economic development (Xiao et al, 2005). As cities expand physically, the frontiers between urban, peri-urban and rural activity distort and merge, thereby, presenting opportunities for beneficial linkages (Rondinelli, 1985; Kaur, 1995).

In developing countries, a substantial and growing proportion of the population lives in or around metropolitan areas and large cities including the peri-urban zone, where their livelihoods depend to some extent on natural resources such as land for food, water, fuel and space for living (Allen, 2001). Rapid growth at the peri-urban fringe has resulted in increased commercial development along arterial roads connecting cities and the countryside (Sullivan and Lovell, 2005). The sustainability of both urban and rural areas is affected by the dynamic and changing flows of commodities, capital, natural resources, people and pollution at the peri-urban interface (Brook and Davila 2000; Allen, 2001). Peri-urban agriculture shall provide a solution to ecologically unhealthy development of large urban agglomerations, whereas urbanization is driven by the desire for short run economic growth and wealth in ever growing cities (Nuppenau, 2002). According to local ecological conditions and habitat, peri-urban agriculture can contribute to preserve natural areas despite the increase of the price of land (Nugent and Drescher, 2000; Borne et al, 2003) to favor intensive production of perishable foods like fruits, vegetables, meat and fish, dairy products. The demand of perishable products can be expected to remain high in urban areas because people living in those areas mainly depend on market supplies for their food consumption as compared to rural people (Jansen et al., 1996). Supplying perishable products to the urban dwellers, peri-urban agriculture can also generate formal and informal employment for farmers themselves as well as food processors and distributors. Many urban farmers, especially women are likely to use income earned from farming on food provision for the family (McGee and Robinson, 1995).

Uncontrolled momentum of urban sprawl and land use change raises many issues (Brook and Davila 2000) which might have both positive and negative impacts in natural, social, and economic environment. Vegetable production in peri-urban areas may face difficulties to survive in the long run due to the scarcity of land and labor resources, unless alternative production technologies become available and the positive externalities generated by the peri-urban agriculture become internalized (Midmore and Jansen, 2003). Better planning and understanding of optimum resource utilization while considering environmental issues, should be given priority for peri-urban areas which may facilitate the criterion of a safe urban environment for human beings. Rapidly increasing population in cities and limited cultivated areas require higher agricultural productivity without polluting soil, air and water (DeBone, 1999). Therefore, urban resources planners in developing countries should give more attention to peri-urban agricultural practices; these could assist in improving urban environment, generating employment and reducing future food insecurity.

Policy makers and other stakeholders concerned with regional rural development increasingly face the need for instruments that can improve transparency in the policy debate and that enhance understanding of opportunities for and limitations to development (Jansen et al., 2005).Understanding the dynamics of complex urban systems and solving the real world problems requires robust methods and technologies for urban resources managers (Wilson, 2006). Spatial organization of urban system can be extracted into GIS as a set of points, lines and spheres to describe the socio-economic properties, linkage interactions and extent of the cities, respectively (Murayama, 2004). Remote sensing provides an efficient tool to monitor long term land-cover changes in and around urban areas whereas geographic information systems provide a framework for spatial analysis and modeling based on geographic principles and seeks to integrate the analytical capabilities to broaden the understanding of the real world system (Goodchild, 1999; Jansen et al., 2005).

The main objective of this paper is to evaluate the land for peri-urban agriculture in the urban fringe area of Hanoi using Geographic Information System (GIS) and Analytical Hierarchical Process (AHP) techniques. The paper presents an empirical land evaluation process emphasizing prominent role of local people and expert’s views in the decision making procedure.

Database and methodology

A case study was carried out in Hanoi province (Fig. 1), Provincial boundaries as administrative units play an important role while preparing local and regional development plans in Vietnam. Therefore, the areas outside the provincial boundary were excluded in the study. The province is located in the Red River delta in northern Vietnam spread over 928 km^2 with flat topography from northwest to southeast. The population of the province was 2.81 millions with an annual 3.2% growth rate where 53.6% population lives in the urban area (CBS, 2001). Urban population in Hanoi is growing rapidly which fueled the demand for timely supplies of fresh vegetables to the cities. Demand of perishable products through peri-urban areas has significantly increased since the change from centrally planned and collective systems to a market economy (Jansen et al., 1996). The competition between demand and supply of land for different activities also plays a critical role in land use morphology of Hanoi urban and peri-urban areas. The peri-urban districts of Hanoi province have to be well planned for regulation of urban development process in the future (HARDD, 2002). Resolution in decentralization of population distribution by establishing small city and satellite towns have to be considered as optimal decisions in strategies for encouraging development at the central city of Hanoi. The province comprises of seven inner urban districts and five surrounding peri-urban districts with agricultural activities (Rossi et al 2002). A map (Fig. 2) prepared based on Baseline Study data (An et al, 2003; Anh et al 2004a) shows that quite a significant demand for vegetables from urban dwellers is supplied by the peri-urban districts of Hanoi and from its surrounding provinces (Anh et al, 2004b). Although it presents only an overview of the vegetable consumption and supply in the province, it does give a picture of the economic interaction between peri-urban and urban areas of the province.

[Fig.1 and Fig. 2, around here]

GIS and AHP techniques in decision making were integrated while assessing the peri-urban land for agriculture (Fig. 3). Understanding the exiting land use pattern greatly helps to the decision/policy makers for identifying the developable spaces in the region and preparing appropriate zoning of land uses. Therefore, updated land use information and major linkage information between peri-urban and urban areas are necessary for optimum peri-urban resource management. A field survey equipped with Global Positioning System (GPS) and still camera was conducted to collect the location-based information. The GPS coordinates and photographs of each location were used for satellite image classification. Local experts meetings and focused group discussions were also accomplished during the field survey period. Based upon intensive discussions made with Hanoi agriculture experts and focused groups (local farmers and community leaders) during field visits, five spatial parameters land use, soil, water, road and market were considered as the most influencing factors in decision making process for peri-urban agriculture in Hanoi. Landsat TM image acquired on November 23, 2001, a soil map, road network map, a topographic map (1:10000) and the field survey data were used as spatial data for the study.

[Fig. 3, around here]

The land use information was extracted from the Landsat image. Supervised classification with Bayesian Maximum Likelihood Classifier was applied to identify major land uses. Furthermore, a 3x3-majority filter was used to remove salt and pepper noises on the map. The accuracy assessment was done using Kohen’s Kappa index where 89% of accuracy was achieved. However, the land use extraction method was constrained by the spatial resolution of satellite imagery, the classification system used, and expert knowledge of the study area (Richards and Jia, 1999). Rivers and ponds/lakes were extracted from the Landsat satellite based land use map and used as a water resource parameter. Based on the field survey data analysis, the water proximities at aerial distance of 1 km, 2 km and 3 km from rivers and 0.3 km, 0.6 km and 0.9 km from ponds/lakes were computed. Similarly, the aerial distances of 1 km, 2 km and 3 km from road network and 10 km, 20 km and 30 km from market zone (inner urban districts of Hanoi) were assigned while computing the road and market accessibility to peri-urban agriculture areas. These distances reflect relative results: the nearer the objects higher the potential for peri-urban agriculture. The areas covered from the chosen distances were subsequently to be considered as suitability classes. The soil map was classified based on Brady (1974) to identify the level of suitability. Each map was further converted into 30 meter grid for spatial analysis.

Depending on the location and the study objective, the contribution level of the selected parameters in decision making process can be different. In this research, the AHP method by Saaty (1990) was used to evaluate the decision making parameters for peri-urban agriculture land suitability. This model evaluates the consistent weight of each parameter through pair-wise comparison (Saaty, 1990; Canada et al, 1996). A set of questionnaires within the AHP framework was developed. In the questionnaire, respondents can determine relative importance of each criterion with respect to other, for example, importance of soil with respect to land use, water, road and market and vice versa. Sets of questionnaires were disseminated to twelve key people in the province covering various backgrounds (local farmers/community leaders, agriculture experts, market experts and agriculture planners) during the field trip. These key people were chosen based on focused group consultation.

Separate matrix was prepared for each respondent. Alltogether twelve matrices were developed. As per the AHP rule, reciprocal computation, value normalization, principal vector weights computation, consistency calculations were performed to the individual matrix, respectively. Nine matrices out of twelve were found consistent. The consistent matrices were further linearly combined using average mean to prepare a final matrix. Then, AHP rule was applied to derive the final weightings. The consistency ratio (CR) coefficient for the final weightings obtained was 0.097 which falls in the acceptable range (CR<=0.10) (Saaty, 1990; Canada et al., 1996). Details of the weight evaluation procedure can be found at Saaty (1990).

Linear combination method (Fig. 3; eq.1) was used to overlay the raster data and integrate the AHP results. In this study, five raster map results (i.e. soil, land use, road accessibility, water resources accessibility and market accessibility) were multiplied by their corresponding AHP weights individually and then all raster data layers were arithmetically overlaid to derive a final suitability map. The map was further scaled into qualitative information (using equal interval method) as High suitable, Medium suitable, Low suitable and Unsuitable land for peri-urban agriculture.

Results

Soil

Eight different types of soil namely, recent alluvial, sub-recent alluvial, mottle alluvial, hydromorphic, alluvial podzolic, gley, faralite mottle and urban soil were found at different locations. Brady (1974) suggested that the recent, sub-recent and mottle alluvial soil contain rich nutrients for crops. Therefore, these kinds of soils are assigned as highly suitable for agriculture. The hydromorphic, alluvial podzolic and gley soils require additional external inputs for crop and vegetable production, therefore these soils are assumed to be of medium suitability. The feralite mottle soil needs very high external inputs to support plants growth, hence, it is considered as of low suitability. The urban soil (bare sandy soil) is unsuitable for agriculture production. The soil suitability map of Hanoi (Fig. 4) demonstrates that the highly suitable soil covers 29% (about 248 km^2) of the province (Table 1). The Red River and the associated streams formed this soil. The locations with these soils are considered highly suitable for agriculture. The soils of medium suitability are found in 267 km^2, about 31% the land of the province. Low suitable soil was found in 78 km^2 (9% of the area). The other types of parcels in soil map such as water bodies, urban soil and unidentified parcels cover about 253 km^2, which are considered unsuitable for agriculture.

[Fig. 4]

[Table 1, around here]

Land use pattern

Based on spectral responses from Landsat imagery, seven types of land use, namely, Bare Soils, Built-up Areas, Forest Cover, Mixed Agriculture, Paddy Field, Residential & Agriculture and Water Bodies (Fig. 5) were identified. The paddy field is recognized as the largest cover, which covers about 290 km^2 of the total provincial land (Table 2). Paddy field and mixed agriculture together occupied about 53% (449 km^2) of the province land can be considered as pure agricultural land. Residential & Agriculture land use occupies about 11% land of the province. This area might involve agricultural practices within the households in order to support their daily needs for vegetables while at the same time earning cash. Another prominent land use is the built-up area. The built-up area covers 123 km^2 land which is a combination of urban houses, industrial houses, and roads where these bodies reflect almost the same electromagnetic energy. Water bodies and forest cover extend to about 132 km^2 and 43 km^2, respectively. Presence of bare soils was nominal. The bare soils were mostly located in riverside flooded area. The parcels of Paddy field and Mixed agriculture are classified as highly suitable areas for peri-urban agriculture whereas Residential & Agriculture parcels are classified as medium suitable land. Remaining types of land use are considered as unsuitable for agriculture.

[Fig. 5, around here]

[Table 2, around here]

Road accessibility

From the field observation, most of the farmers use motorbike and bicycle as daily means of transportation to commute to the markets in urban districts. Some farmers also commute by foot. More often, farmers go to market in early morning to sell their goods and in the evening to acquire market information. In peri-urban areas of Hanoi, roads account for 1030 km (Fig. 6, Table-3). The existing roads, based on their condition, are differentiated into four types, namely, All Weather, Main Earth, Paved Surface and Railroads. These roads play a crucial role in interlinking several communes of the twelve districts of Hanoi as well as other provinces of the country. The accessibility of the physical transportation network shows that a large part of the province is highly accessible. About 753 km^2 is covered by the zone and 75 km^2 falls in between 1-2 km aerial distance from the physical transportation network. A few parts, about 2% of the peri-urban area are 2 km from the road network. Small spatial units of the Soc Son and Than Tri districts were found to be inaccessible because people from that unit have to walk more than 3 km of to reach an accessible road. However, the road linkages in the province are very accessible and facilitate the transportation of rural products to the urban market. Therefore, there is a great potential for peri-urban agriculture. Farmers of those areas can easily market their agricultural products to the city dwellers.

[Fig. 6 and Fig. 7, Table 3, around here]

Water resources accessibility

The water resources layer was prepared from the Landsat based land use map (Fig. 5). The total coverage of water resources in the peri-urban area is 132 km^2 (Table 4) where rivers and lakes cover about 48% and 52% area, respectively. Water resources are being used for aquaculture, irrigation, transportation and recreational purposes. Peri-urban agriculture fully depends on these water resources. Traditional and modern techniques have been observed for irrigation systems. Pumping and small canal techniques are used in lakes and ponds. The modern canal systems supply water from the rivers to agriculture land. The accessibility of water resources was measured based on the rivers and lakes. Fig. 7 shows that a total of 414 km^2 area falls into the high accessibility zone of water resources, which covered 49% of total land. About 173 km^2 and 75 km^2 are found in medium and low accessibility of water resources, respectively. Forty two square kilometers of Soc Son lands have very difficult access to water resources. Few areas of the Tu Liem and Dong Anh district also face the same problem. Such areas fall into the inaccessible zone of water resources for peri-urban agriculture. [Table 4, around here]

Market accessibility

Fig.2 and Table 6 show that most of the vegetable products in Hanoi are sourced from peri-urban districts i.e. Dong Anh, Gia Lam, Tu Liem and Thanh Tri. Some provinces of

Vietnam and China are also providing vegetable products into the urban Hanoi. The map shows that there is a significant linkage between the peri-urban and urban as well as areas outside the Hanoi province in different directions. The market accessibility map (Fig. 8) suggests that 474 km^2 of the peri-urban district has high accessibility to market, the whole of Thanh Tri and Tu Liem districts are in the high accessibility zone (Table 5). Most of the Dong Anh and Gia Lam districts are near to the market center. For the high accessible zone, the farmers can easily secure their market information needs and supply their agricultural products to the urban areas due to proximity to market. They can also access their daily basic needs from the city center. The Soc Son district seems very far from the Hanoi market access. About 49% of the total area of the district is found in the medium accessibility zone. Around 3% of northern part of Soc Son district is unable to access the market center easily. It can be solved through the provision of transportation infrastructure but additional transportation cost may raise the price to the products.

[Table 5, around here]

Land allocation for peri-urban agriculture

Five geographic maps namely, Soil (Fig. 4), Land use (Fig. 5), Road accessibility (Fig. 6), Water accessibility (Fig. 7) and Market accessibility (Fig. 8) were used as major maps for identifying the suitable land for peri-urban agriculture. The land suitability assessment has been performed in peri-urban districts of Hanoi province. Based on the AHP method, the soil is identified as the most important indicator for agriculture, which has 37 weights (Table 6). The second most important indicator is land use assigned a weight of 31. The other indicators road, water resources and market have been assigned a weight of 16, 10 and 6, respectively. All decision parameters with their corresponding weights were linearly combined.

[Table 6, Fig. 8 and Fig. 9, around here]

In Hanoi peri-urban area, a total of 438.33 km^2 (52%) is found as arable land (Table 7). The resultant map of suitable land for peri-urban agriculture (Fig. 9) shows that 308 km^2 (36%) area of arable land is highly suitable, 115 km^2 (14%) is medium suitable and 14 km^2 (2%) is low suitable. An area of 110 km^2 (13%) area was found to be unsuitable. It may be due to the lack of fertile soil, water resources accessibility, among others. The rest of the area (35%) of peri-urban is either covered by the water resources, built-up or forest cover. In the highly suitable land, the coverage of 84 km^2 is in the Dong Anh district (northern) alone whereas the two districts, namely, Soc Son and Gia Lam have similar area of 77 km^2 while the remaining two districts have the area which ranges from 33-36 km^2. About 87 km^2 area is accounted as medium suitable land for peri-urban agriculture in the Soc Son district. The Dong Anh district has only 15 km^2 of medium suitable land area. Three more districts with 2-6 km^2 fall under the medium unsuitable land. Only 14 km^2 is in the low suitable category, mostly in Soc Son district. An addition, a total of 51 km^2 in the Soc Son district was found as unsuitable for peri-urban agriculture. Some areas comprising about 20 km^2, 18 km^2, 10 km^2

and 10 km^2 of lands in Dong Anh, Gia Lam, Tu Liem and Than Tri, respectively, also fall into the unsuitable category.

[Table 7, around here]

Discussion and concluding remarks

The ten-year Hanoi provincial master plan and policy documents about peri-urban agriculture (HARDD, 2002) were also reviewed. Priority is given by these to the development of peri-urban agriculture at institution level with business perspectives. Emphasizing market demand based agricultural specializations; focus is given to the suburban economic development through urban agricultural development. Identifying the suitable zone for peri-urban agriculture and developing special products areas: clean vegetables, fruits, pork and fish may play an important role for economic growth as well as food security. The integrated technique of GIS and AHP evaluated the land of peri-urban area of Hanoi at different scale of suitability for peri-urban agriculture which may support to improve government plan and land use policy in some extent. Consolidation of local people knowledge and expert's views with modern geographic techniques to evaluate the peri-urban land leads this research results more empirical and original.

Although the AHP (Saaty, 1990) method is widely accepted in solving multi-criterion problems, the accuracy of the results depends on available sources of spatial data. Moreover, the selection of land suitability assessment parameters, priority weights within the AHP framework are greatly influenced by objectives, location, topography, people involved in discussions and key informants. However, this paper provides a thematic framework including opportunities and limitations of Hanoi peri-urban area to the Vietnamese provincial planners. Every level of suitability can be utilized for different purposes, for example, the unsuitable land for peri-urban agriculture may be used to establish industrial estates. The low suitable land can be checked for fish farming or dairy farming or other species based on their requirements. Separate assessment is recommended before making appropriate decision for alternative use of land. If the planners and decision makers of the Hanoi province follow such integrated scenario while making decision for allocating economic activity zones in peri-urban areas, the land use might be sustainable. Therefore, government policy plays a crucial role for sustainability of the peri-urban agriculture.

This paper shows an empirical land assessment technique integrating GIS and AHP which may help the policy makers for rapid assessment. To understand the complexity of the urban fringe, geographically referenced maps and local key informants are very important. In this research, the techniques applied in this field survey (location information collection, experts meetings and focused group discussions) have played a very important role in rapid data acquisition at the grassroot level. Remote sensing techniques assessed the recent land use information cost effectively. This empirical method accepts key input from experts and local people through group discussion and questionnaire survey, which significantly enhance the decision making capabilities while preparing the land use plan. The AHP framework provides this platform very efficiently. Integrating local knowledge in the method has shown the people participation in land use planning. The method was able to map the suitable land for a peri-urban agricultural activity precisely. More decision factors can be added if deemed necessary. The selection of decision factors is case dependent because influencing factors in decision can differ from place to place. As for Hanoi peri-urban area, decision factors are selected based on focused group discussion analysis. The government policy is also being focused towards the sustainable peri-urban agriculture. Although this paper does not discuss some issues such as the urbanization patterns in Hanoi and negative impact on soil environment due to vegetable cultivation malpractices as argued by Midmore et al. (1996), the application of this paper will be useful to policy makers and urban and regional planners to manage peri-urban resources and provide services to the people living in the rapidly changing environment especially in developing countries. The scenario also provides a framework to the urban researchers for rapid information acquisition within a short duration.

Acknowledgements

The authors would like to thank CIRAD-Vietnam, VTGeo and RIFAV for their contribution to the field trip arrangement, baseline survey and spatial data. We owe a debt of gratitude to the people for sharing their knowledge, experiences and opinions during the research period as well as the anonymous reviewers for their creative comments; they were all helpful in the revision of this manuscript.

References

Adell G, 1999. Theories and models of the peri-urban interface: a changing conceptual landscape. Strategic Environmental Planning and Management for the Peri-urban Interface (Research Project Report), Development Planning Unit, University College London, UK.

Allen A, 2001. Environmental planning and management of the periurban interface. In proceedings of the Conference on Rural-Urban Encounters: Managing the Environment of the Periurban Interface, London, UK.

An H B, Vagneron I, Thinh L N, Dam D D, Hang L T, Thoai T Q, Moustier P, 2003. Spatial and institutional organization of vegetable market in Hanoi. Retrieved November 2005 from Sustainable Development of Peri-urban Agriculture in South-east Asia (Susper) Project website at http://www.avrdc.org/susper/publicationpage.htm

Anh M T P, Ali M, Anh H L, Ha T T T, 2004b. Urban and peri-urban agriculture in Hanoi: Opportunities and constraints for safe and sustainable food production. Shanhua, Taiwan: AVRDC – The World Vegetable Center, Technical Bulletin No. 32, AVRDC Publication 04-601.

Anh M T P, Loc N T T, Thinh L N, Son H T, Moustier P, 2004a. Basic information on the project sites in Hanoi peri-urban areas. Retrieved at November 2005 from Sustainable Development of Peri-urban Agriculture in South-east Asia (Susper) Project website at http://www.avrdc.org/susper/publicationpage.htm.

Borne F, Satornkich J P, Anwar S M, 2003. Plant modeling for landscape changes visualization: Application to a Peri-urban agricultural area. In proceedings of the International Symposium on Plant growth Modeling, simulation, visualization and their Applications PMA03 Conference, Beijing, China.

Brady N C, 1974. The nature and properties of soils. NY/London, McMillian Publishing Company.

Brook R M, Davila J D, 2000. The peri-urban interface: A tale of two cities. School of Agricultural and Forest Sciences, University of Wales and Development Planning Unit, University College London, UK.

CBS, 2001. Hanoi statistical year book. Central Bureau of Statistics, Vietnam.

Canada J R, Sullivan W G, White JA, 1996. Capital investment analysis for engineering and management. New Jersey 07458, NJ: Prentice-Hall.

De Bon H, 1999. Safe and year round vegetable production in peri-urban areas. In proceedings of the National Workshop, RIFAV and CIRAD, Hanoi, Vietnam.

Goodchild M F, 1992. Geographical information science. International Journal of Geographical Information Systems 6, 31-45.

HARDD, 2002. Ten-year (2001-2010) master plan and policies for peri-urban agriculture. Hanoi Agricultural and Rural Development Department, Vietnam.

Jansen H G P, Bouman B A M, Schipper R A, Hengsdijk H and Nieuwenhuyse A, 2005. An interdisciplinary approach to regional land use analysis using GIS, with applications to the Atlantic Zone of Costa Rica. Agricultural Economics, 32, 87-104.

Jansen H G P, Midmore D J, Binh P T, Valasayya S and Tru L C, 1996. Profitability and sustainability of peri-urban vegetable production system in Vietnam. Netherlands Journal of Agricultural Science, 44, 125-143.

Kaur R, 1995. Urban-rural relation: A geographical analysis. Anmol Publication Pvt. Ltd, India.

McGee T G, Robinson I M, 1995. The mega-urban regions of Southeast Asia. UBC Press, Canada.

Midmore D J and Jansen H G P, 2003. Supplying vegetables to Asian cities: is there a case for peri-urban production? Food Policy, 28, 13-27.

Midmore D J, Jansen H G P and Dumsday R G, 1996. Soil erosion and environmental impact of vegetable production in the Cameron Highlands, Malaysis. Agriculture, Ecosystems and Environment, 60, 29-46.

Murayama Y, 2004. American influence on Japanese human geography: A focus on the quantitative and GIS revolutions. GeoJournal 59, 73-76.

Neuppenau, E. A., 2002. Agro-Ecologically Oriented Land Use and the Creation of Viable Rural Urban Interfaces. 2nd Newsletter March 2002 Peri-urban Development in South East Asia.

Richards J A, Jia X, 1999. Remote sensing digital image analysis. Springer, Germany.

Rondinelli D A, 1985. Applied methods of regional analysis: the spatial dimension of development policy. Westview Press, Boulder and London.

Rossi G, Cu P V, Quertamp F, Chabert O, 2002. Atlas infographique de la province de Hanoi [Atlas of Hanoi Province]. VTGEO-Institut de Géologie, CNST Vietnam / UMR CNRS-IRD 9937 "REGARDS", France

Saaty T L, 1990. Multi criteria decision making – the Analytic Hierarchy Process. RWS Publication, Ellsowrth Avenue, USA.

Sullivan W C, Lovell S T, 2005. Improving the visual quality of commercial development at the rural-urban fringe. Landscape and Urban Planning (in press).

Tacoli C, 2001. Livelihoods impacts and strategies of the periurban poor. In proceedings of the Conference on Rural-Urban Encounters: Managing the Environment of the Periurban Interface, London, United Kingdom.

Wilson A G, 2006. Ecological and urban systems models: some explorations of similarities in the context of complexity theory. Environment and Planning A, 38, 633-646.

Xiao J, Shen Y, Ge J, Tateishi R, Tang C, Liang Y, Huang Z, 2005. Evaluating urban expansion and land use change in Shijiazhuang, China by using GIS and remote sensing. Landscape and Urban Planning (in press).

Zeng H, Sui D Z, Li S, 2005. Linking urban field theory with GIS and remote sensing to detect signatures of rapid urbanization on the landscape: toward a new approach for characterizing urban sprawl. Urban Geography, 26, 416-434.

Table 1. — Soil suitability classification

District	Soil Suitability (area in km^2)				Total Area
	High	Medium	Low	Not	
Soc Son	31.64	138.62	72.92	62.36	305.55
Dong Anh	53.95	68.90	4.34	58.64	185.83
Gia Lam	83.63	30.21	0.32	61.23	175.39
Tu Liem	44.15	12.94	0.06	22.52	79.68
Thanh Tri	34.45	16.49	0.00	48.55	99.49
Total Land	247.81	267.16	77.65	253.31	845.93
Percent (%)	29.29	31.58	9.18	29.94	100.00

Table 2. —Land use pattern in Hanoi province

Districts	Land Use Legend (area in km^2)							Total Area
	PF	MA	R&A	FC	BuA	BS	WB	
Soc Son	72.99	83.44	73.46	42.17	2.17	-	31.30	305.55
Dong Anh	64.98	46.32	8.49	-	34.84	0.24	30.96	185.83
Gia Lam	69.22	23.68	7.95	0.53	42.55	0.39	31.04	175.37
Tu Liem	40.22	4.76	3.67	-	23.16	0.23	7.68	79.72
Thanh Tri	35.43	8.27	4.14	-	20.89	0.11	30.66	99.49
Total	282.84	166.47	97.71	42.71	123.62	0.97	131.64	845.96
Percent (%)	33.43	19.68	11.55	5.05	14.61	0.11	15.56	100.00
Suitability	High	High	Medium	Not	Not	Not	Not	

Note: PF= Paddy Field, MA= Mixed Agriculture, R&A= Residential & Agriculture, FC= Forest Cover, BS= Bare Soils, BuA= Built-up Area and WB= Water Bodies.

Table 3.—Road network accessibility

Districts	Road Length (km)	Accessibility (km^2)				Total Area
		High	Medium	Low	No	
Soc Son	324.49	269.32	27.62	6.86	1.75	305.55
Dong Anh	246.04	175.13	10.70	0	0	185.83
Gia Lam	218.99	149.27	22.71	2.62	0.77	175.37
Tu Liem	141.88	77.26	2.42	0	0.04	79.72
Thanh Tri	98.89	82.06	11.22	4.68	1.53	99.49
Total	1030.30	753.04	74.67	14.16	4.10	845.96
Percent (%)		89.02	8.83	1.67	0.48	100.00

Table 4. — Water resources and accessibility

Districts	Resources (km^2)		Water Resources Accessibility (km^2)				Total
	Rivers	Lakes	High	Medium	Low	Not	Area
Soc Son	20.98	10.33	141.24	59.94	30.89	42.18	305.55
Dong Anh	13.77	17.19	101.88	35.84	13.87	3.28	185.83
Gia Lam	18.64	12.40	93.92	38.53	11.24	0.66	175.39
Tu Liem	4.69	2.99	29.08	23.82	14.18	4.92	79.68
Thanh Tri	5.57	25.08	48.08	15.10	5.26	0.39	99.49
Total	63.65	67.99	414.20	173.22	75.44	51.44	845.94
Percent (%)	7.52	8.04	48.96	20.48	8.92	6.08	100.00

Table 5. — Market accessibility

Districts	Vegetables	Accessible Area in km^2				Total
	Input%*	High	Medium	Low	Not	Area
Dong Anh	25.51	156.32	29.51	0	0	185.83
Gia Lam	14.28	138.11	37.28	0	0	175.39
Soc Son	n.a.	0.07	149.84	145.30	10.34	305.55
Thanh Tri	8.34	99.49	0	0	0	99.49
Tu Liem	9.47	79.68	0	0	0	79.68
Total	57.6	473.67	216.63	145.3	10.34	845.94
Percent (%)		55.99	25.61	17.18	1.22	100.00

*To Hanoi urban area.

Table 6. — Weights* of individual variables

Indicators	Weights
Soil	37
Land use	31
Road	16
Water	10
Market	6

*Weights are computed based on AHP guidelines (Saaty, 1990).

Table 7. — Suitable land for peri-urban agriculture

Peri-urban Districts	Suitability Area (km^2)				Exclude Area	Total Area
	High	Medium	Low	Not		
Soc Son	77.71	86.97	14.22	51.01	75.64	305.55
Dong Anh	84.31	15.3	0.18	20.24	65.8	185.83
Gia Lam	77.35	5.99	0.03	17.87	74.14	175.38
Tu Liem	35.63	2.76	0.01	10.48	30.8	79.68
Thanh Tri	33.47	4.35	0.04	10.08	51.55	99.49
Peri-urban:	308.48	115.36	14.49	109.67	297.93	845.93
Percent (%)	36.47	13.64	1.71	12.96	35.22	100.00

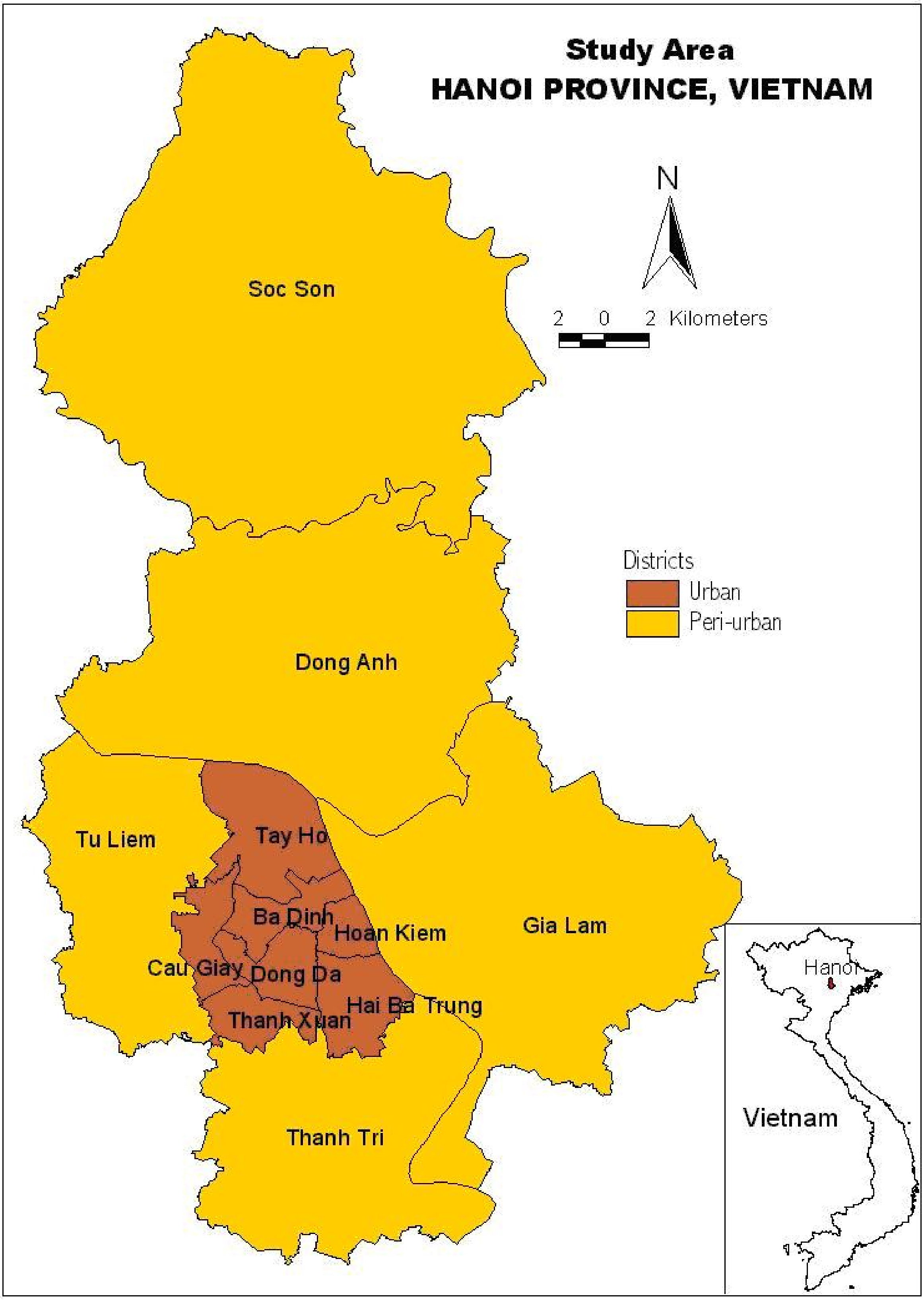

Fig. 1. Study area, Hanoi province, Vietnam.

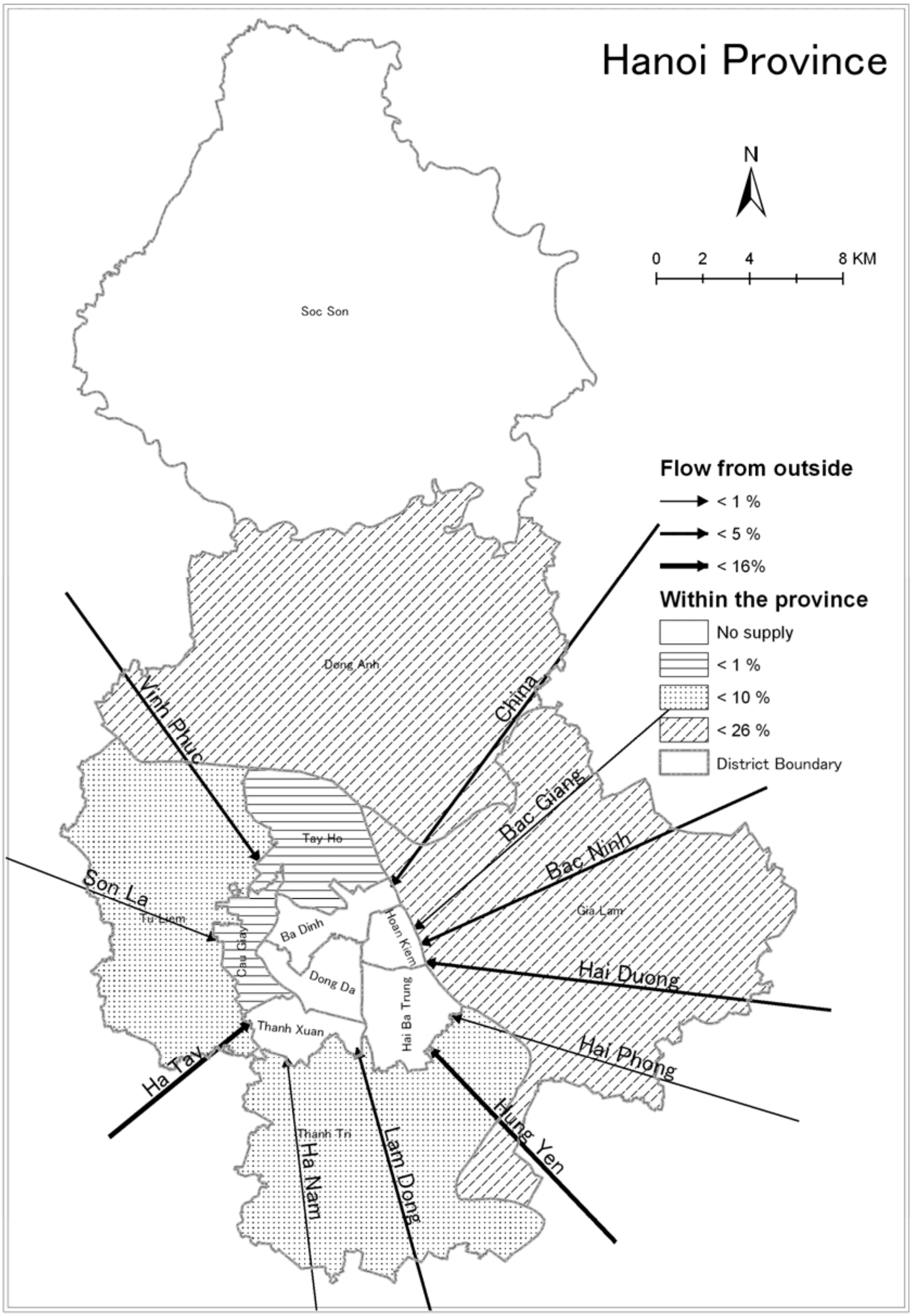

Fig. 2. Vegetables input linkages.

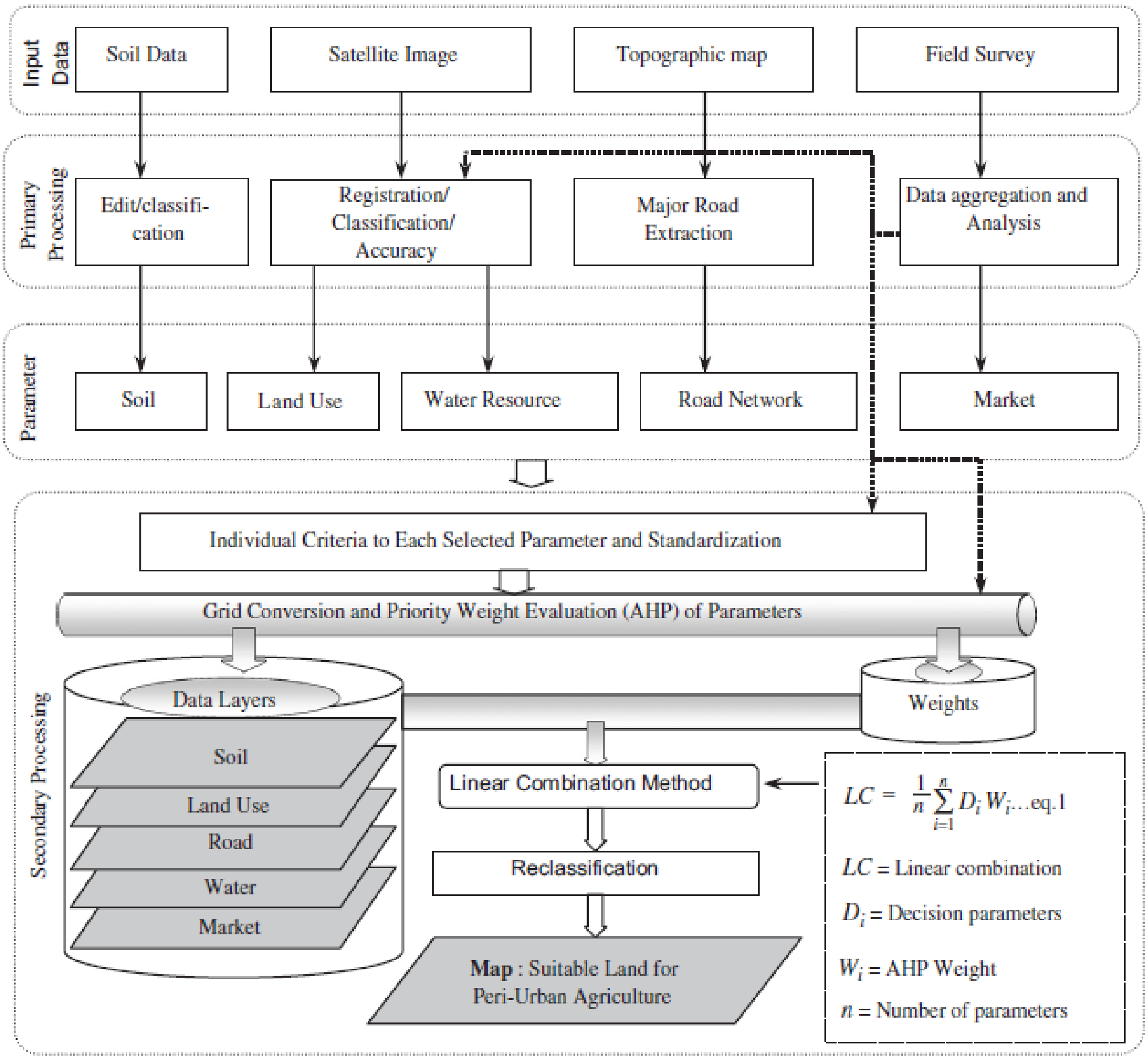

Fig. 3. Land assessment method for peri-urban agriculture.

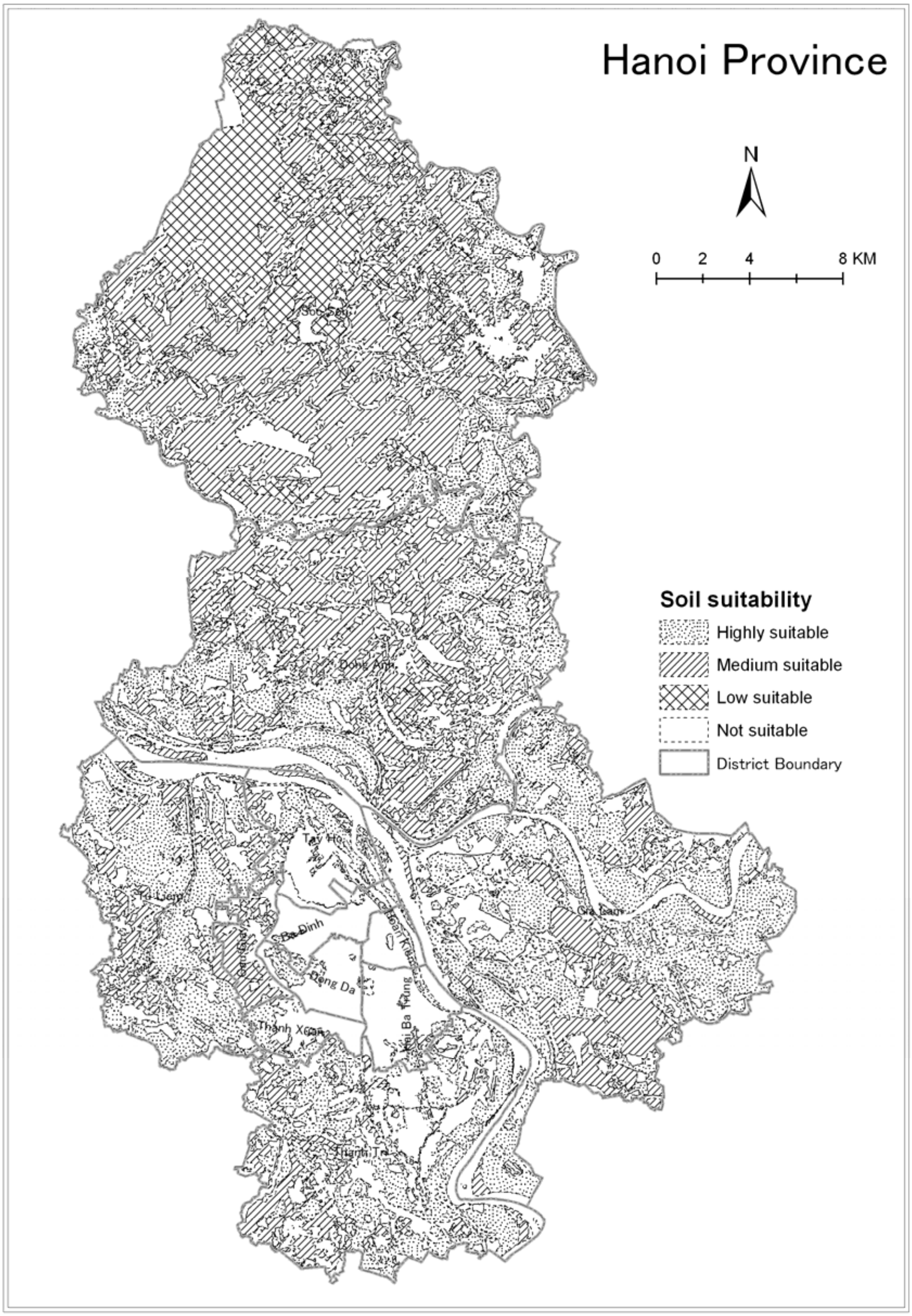

Fig. 4. Soil suitability.

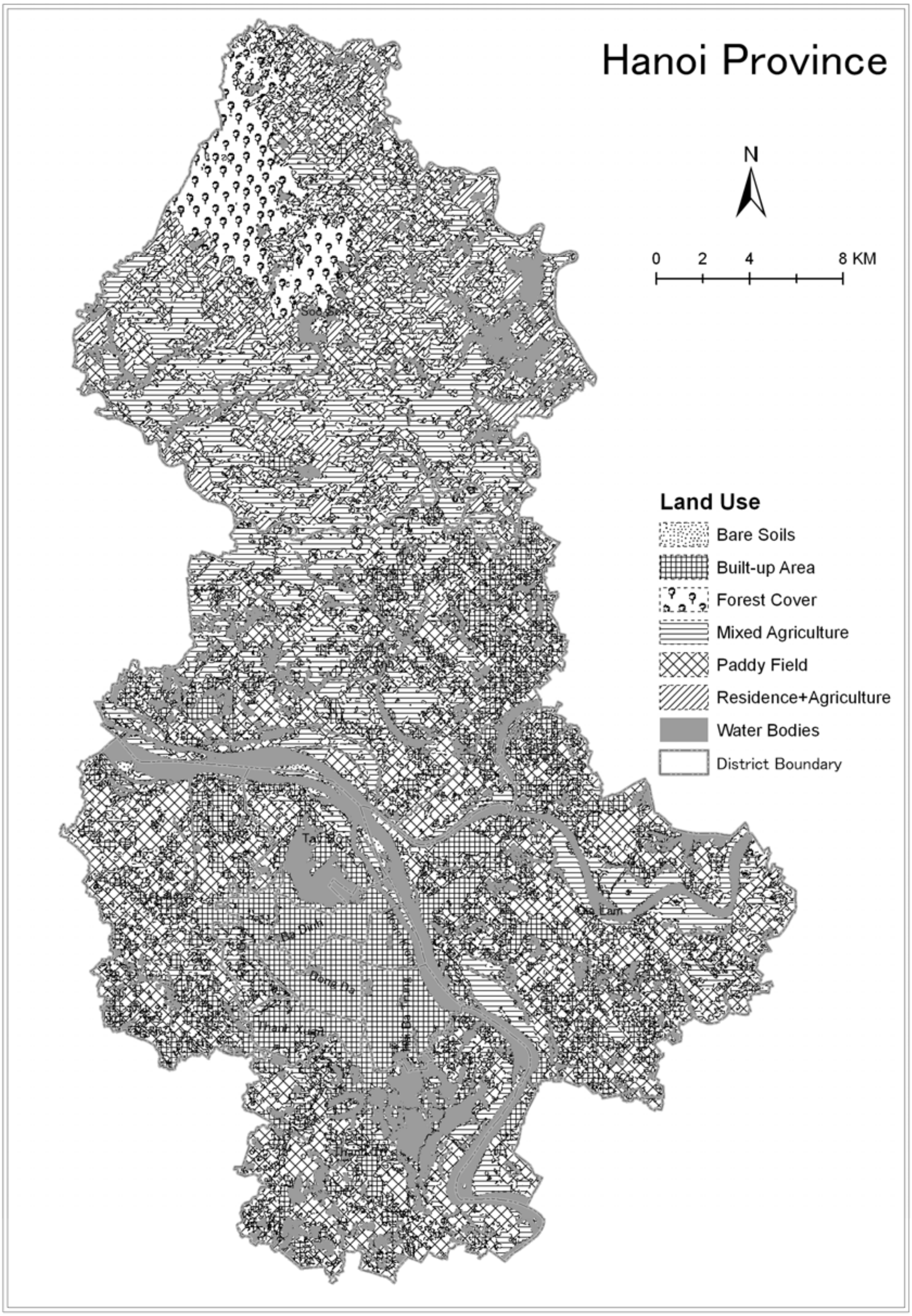

Fig. 5. Land use map (2001).

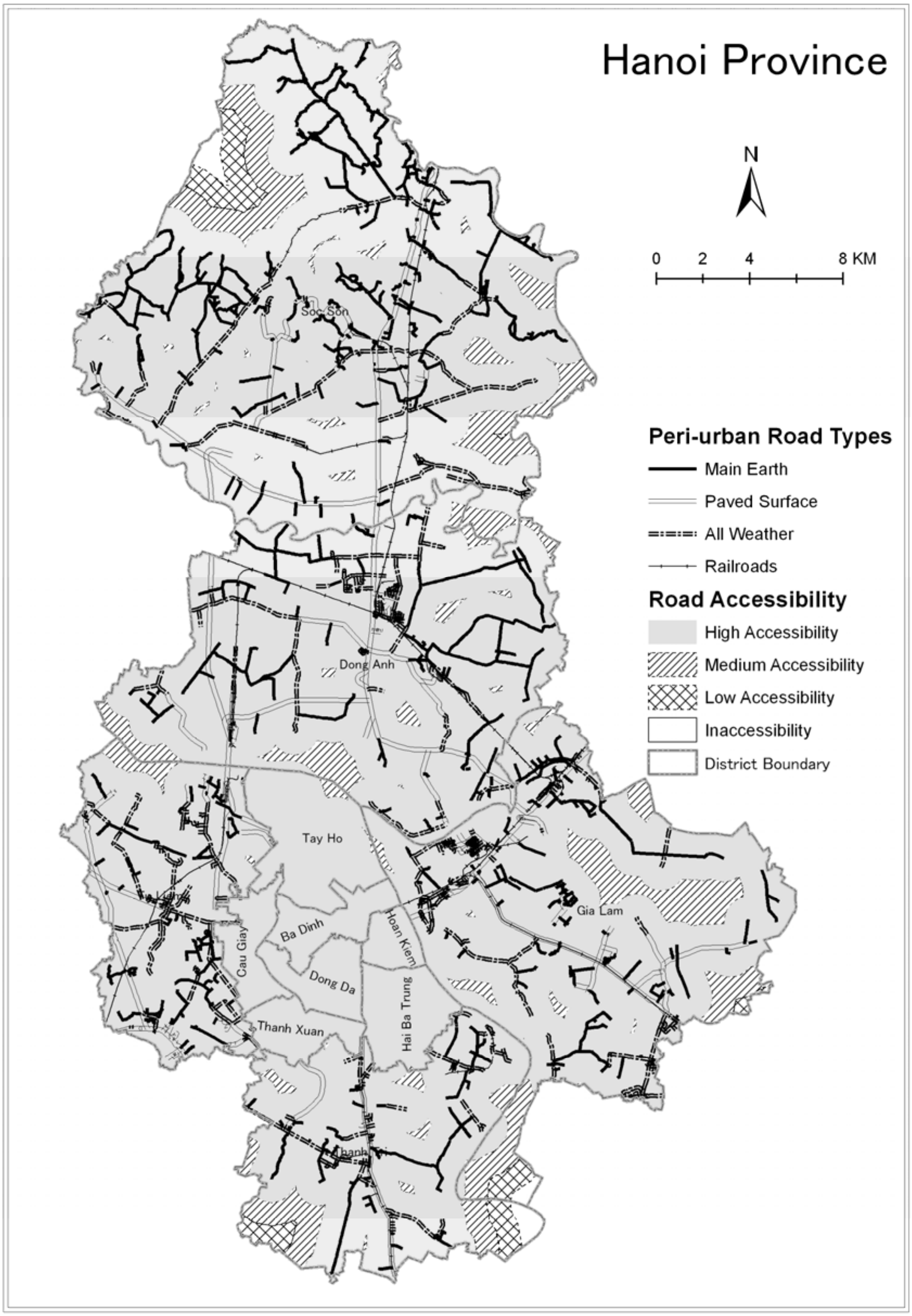

Fig. 6. Road accessibility.

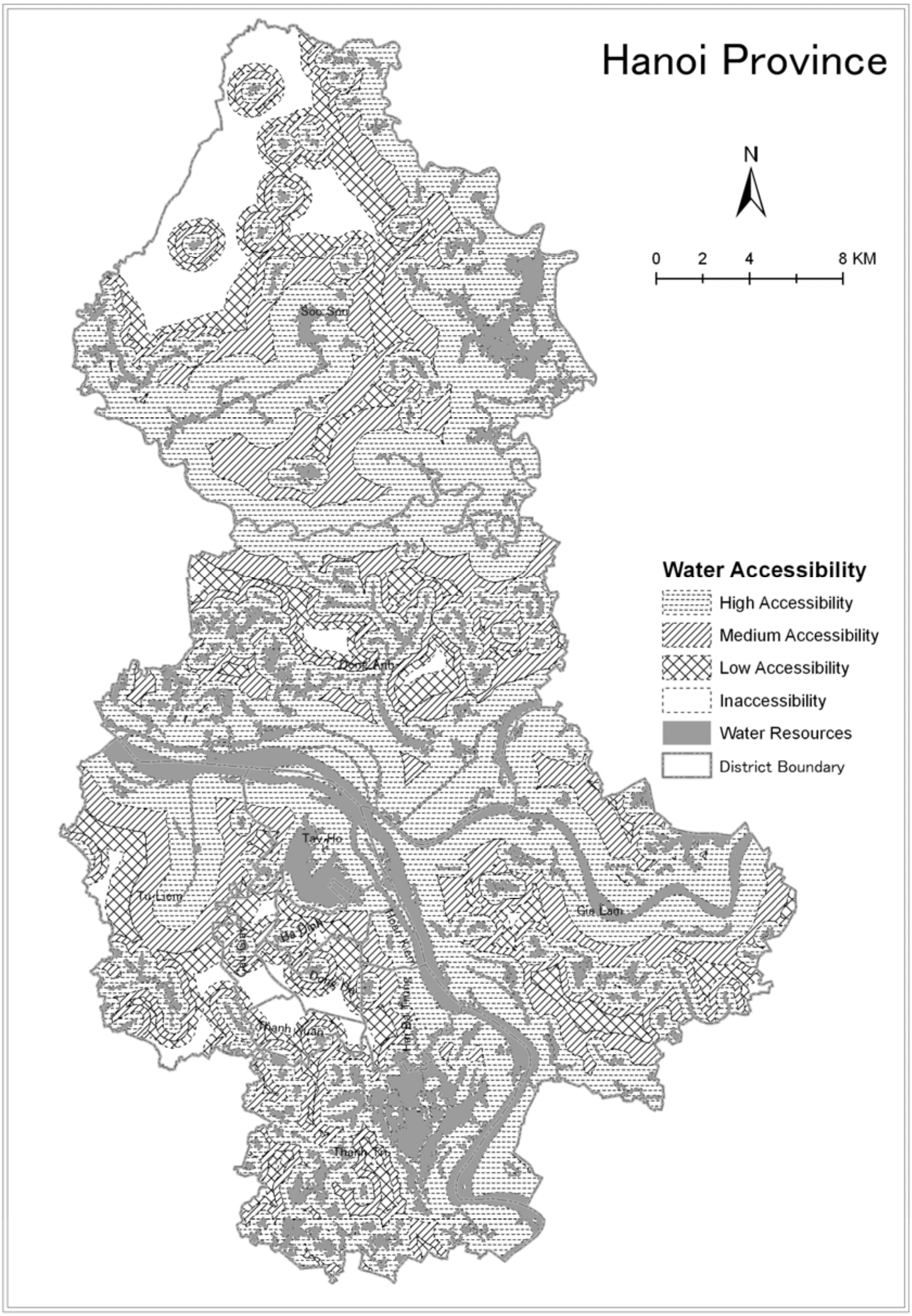

Fig. 7. Water resources accessibility.

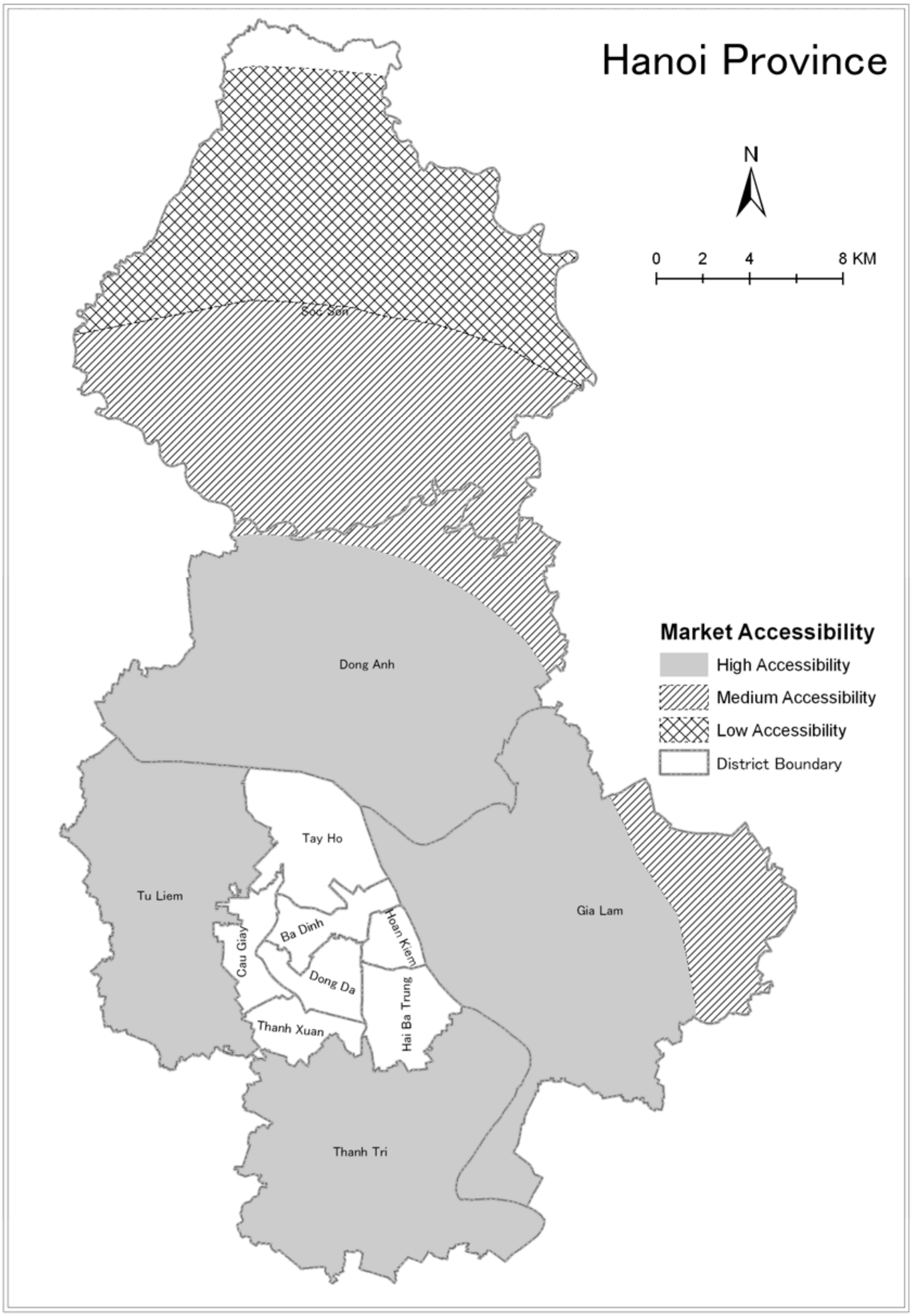

Fig. 8. Market accessibility.

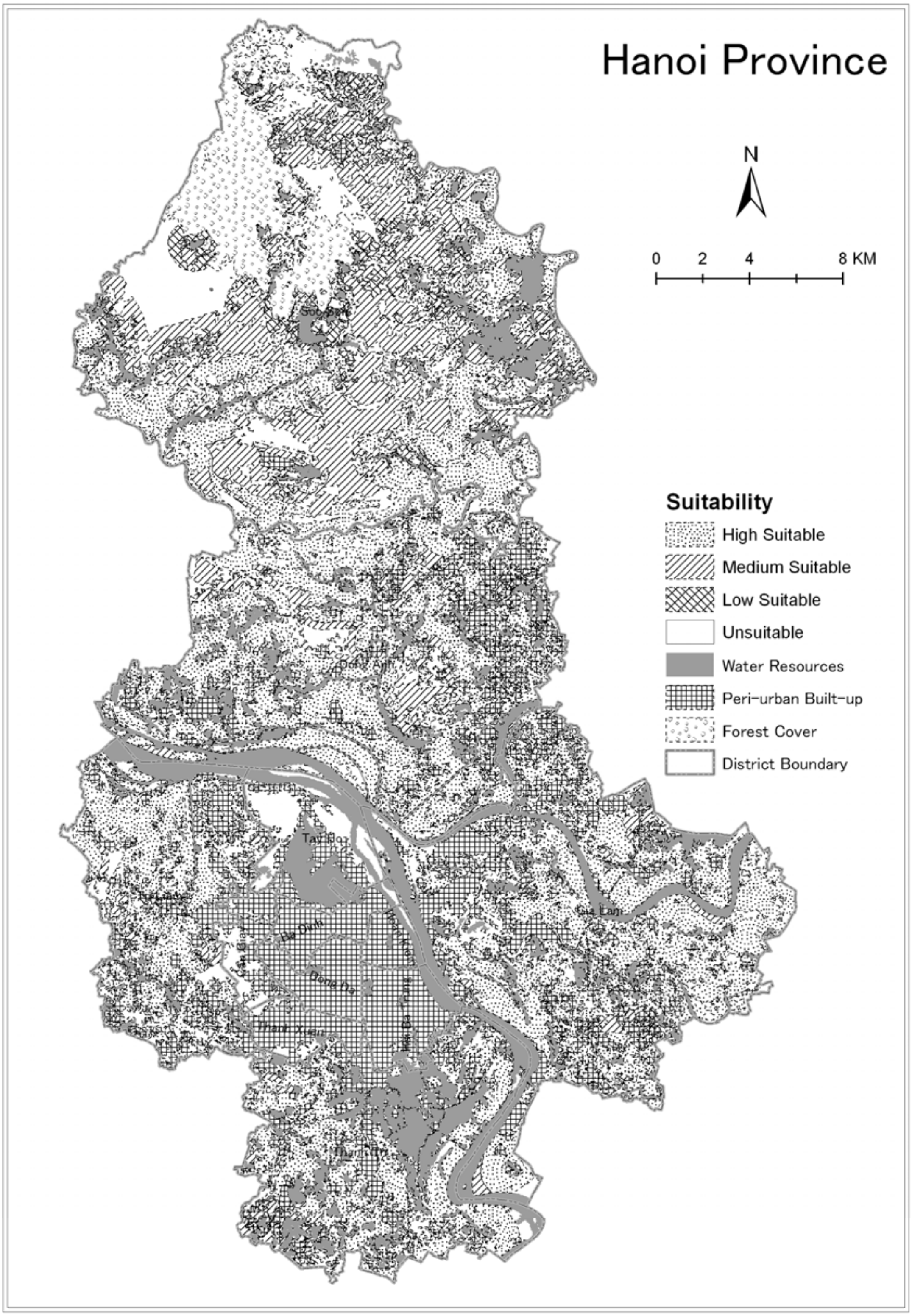

Fig. 9. Suitable land for peri-urban agriculture.