Sustainable Earth Review 2(3) 2022 55-65

Sustainable Earth Review

Journal homepage: http://sustainearth.sbu.ac.ir

Monitoring the Impacts of City Sprawling on Urban Agriculture Lands; The Case of Hamadan City, Iran

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A B S T R A C T

While the issue of healthy and nutritious food provision for all has become one of the major challenges of global development, urban sprawl increasingly threatening the urban and peri-urban agriculture. However, urban agriculture is one of the most efficient policy to environmental protection, urban resilience and promotion of food security, particularly for poor urban residents. Accordingly, through the analysis of satellite images, using the GIS and remote sensing tools, this paper quantifies the LUCC and urban growth that occurred between 1984 and 2014 in the Hamadan city. It also simulates future urban growth, using CA-Markov Chain Model. The results revealed that urban sprawl over the 1984-2014, led to loss of 3199.5ha of orchards, irrigated and irrigated agricultural lands in Hamadan city. Our simulations suggest that this unsustainable trend will be continued up to 2024. This trends not only threatens urban food security but also will lead to excessive car dependence, poverty increase, loss of local jobs, more pollutions and GHG emission, and result in a decline of city livability. The policies relying on compact city approach, establishing green belt and directing the new growth demand to satellite towns should be advocated.

A R T I C L E I N F O

Keywords:
Agriculture lands
Hamedan city
Land use/cover change
Urban sprawl

Article history:
Received: 19 Jan 2022
Accepted: 29 Feb 2022

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1. Introduction

Nowadays, the issue of security for the provision of healthy and nutritious food for world's population has become one of the major challenges of global development (FAO, 2009; United Nations, 2012). On one hand, the rapid growth of urbanization, especially in developing countries, (United Nations, 2014) increasing income and the changing patterns of food demand, particularly biofuel, led to a sharp increase in food and agriculture product demand (FAO, 2009; Akram-Lodhi, 2008; Hille et al., 2012). On the other hand, climate change and land degradation as well as the water supplies reduction, (World Resources Institute, 2003; UNEP, 2011; Battersby, 2012) and the parallel speculation in food markets and regional conflicts (Akram- Lodhi, 2008; Brahmbhatt, and Christiaensen, 2008) have affected food supplies. Currently, 840 million people are unable to meet their food and energy basic needs (FAO, 2013). In MENA, this condition has exacerbated by drought, conflicts, higher vulnerability to climate change, and water crisis. In addition, and heavy reliance on food imports led to naming the region as the most food-insecure region in the world (Tawk et al., 2014).

In this challenging and uncertain world, unsustainable urban forms such as urban sprawl have worsened conditions over the last six decades. Urban sprawl, in general, refers to certain city spatial expansion towards suburbs and the peripheral area with, low density, single-use, extensive road and highway networks, car-dependent, scattered, and ribbon development (Galster et al., 2001; Hasse and Lathrop, 2003). Urban sprawl has many negative environmental, socio-economic impacts, particularly on urban and peri-urban agriculture. However, urban agriculture has been recognized as one of the most important factors to environmental protection, (Romero and Ordenes, 2004; Kasper and Rau, 2012) urban resilience (McClintock, 2010; World Meteorological Organisation, 2007), promotion of food security, particularly for urban poor (De Zeeuw et al., 2007; FAO et al., 2005), and vitality of local economy and livability of cities (Richter et al., 1995; De Zeeuw et al., 2007). The impacts of the spatial expansion of cities on urban and peri-urban agricultural are both direct and indirect. Indirect effects including conversation of agriculture land to build up area and reduced food production, and increased the cost to maintain agriculture land (OECD, 1979; del Mar López et al., 2001; Allen and Lu, 2003; Atu et al., 2012). The major indirect effects largely associated with sprawl-related GHG emission (Lee et al., 1998; Allen and Lu, 2003; Sumner et al, 2010; Tong and Chen, 2002; Glaeser and Kahn, 2004) and increased impenetrable surface and result in higher temperatures, increased flood hazard (Bhatta, 2010; EEA, 2006; Sung et al., 2013), potentially deterministic changes in diseases, pests, weeds (Keane et al., 2009) and serious effects on water quality and quantity. It also led to higher input and operation costs and a decline in labor productivity in urban agriculture by excessive fuel prices, infrastructure and public service costs (Lee et al, 1998; EEA, 2006; Sung et al., 2013; UN-HABITAT, 2010), and reduced social cohesion, public health, safety and security (EEA, 2006; Freeman, 2001). The urban agriculture plays a crucial role in the developing countries such as Iran, due to the large share of employment in this sector, (Redwood, 2012; Shahbazi and De la Rosa, 2010; Sumner et al., 2010) the delicate ecological balance, limited soil and water resources and high vulnerability to climate change (Shahbazi and De la Rosa, 2010; Amiri and Eslamian, 2010; Mahmoudi et al., 2011). In addition, Iran is a net food importer (Ministry of Agriculture Jihad, 2015). The rapid growth of urbanization (the number of cities and urban population from 1976 to 2011 have become 3.4 times for both) (Statistical Centre of Iran, 2011) and the situating of large cities in the heart of fertile plains, required crucial attention to prevent urban sprawl and protect farmlands. However, like most of the developing countries, Iran has experienced dominant of urban sprawl and urban fringes land use change over the last five decades (Shahraki et al., 2011; Mohammady, 2014; Ebrahimpour-Masoumi, 2012). Hamadan city is one of such cities that over the last few decades has experienced rapid population growth and low-density physical expansion in urban fringes. Understanding land-use changes and urban growth trends in Hamadan can facilitate environmental and socio-economic sustainability by improving land management and urban planning, promoting the capability of assessing and predicting future land-use change and urban growth trends, and producing new data and knowledge on key land-use processes (Veldkamp and Lambin, 2001). Accordingly, this paper aims to map and analyze the city expansion and its impacts on urban agriculture lands using the spatial and temporal technologies such as GIS and remote sensing and finally recommended some appropriate policies.

2. Material and Methods

2.1. Study area

Hamadan city located in the west of Iran, situating on a plain –Hamadan-Bahar Plain – with an area of 930 km2 which is one of the most fertile plains in Iran. City’s population is 525, 794 people (Statistical Centre of Iran, 2011) and during last 35 years, the city's population has increased more than 3.17 times. The city has divided into 4 districts. Fig. 1 represents an overview of Hamadan and the geographic location of the city.

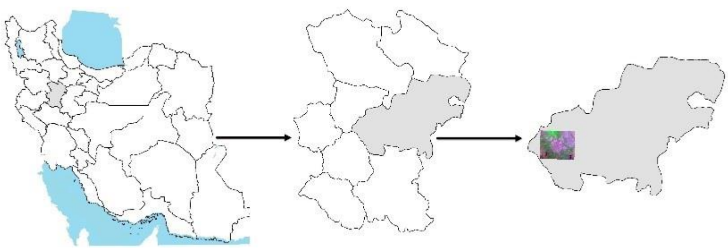

Fig. 1. Location of Hamadan City

2.2. Data sets, processing and Methods

The over the last few decades, the GIS and remote sensing techniques has attracted more interests from scholars and have largely proved to be effective tools for mapping and monitoring of urban sprawl and land use changes (Masser, 2001; Yeh and Li, 1997; Jat et al., 1997; Haack and Rafter, 2006). Accordingly, Landsat TM satellite images for the years 1984, and 2014 (Fig. 3) were utilized for assessing and monitoring Hamadan LULC changes and growth. In supporting the study, secondary data, as a reference data were obtained from the different Hamadan's organizations. The City land use maps and the demographic details were obtained from Iran's Census Center and Hamadan municipality. The different bands of the Landsat images were arranged to get an untrue color composite image. All the bands and their traits have been presented in Table 1. The supervised classification by IDRISI ANDES 16 was used to process and classify the images of the Hamadan city. The Artificial Fuzzy methods were employed to create a classified image, at a 30 m resolution and a projection system (UTM-WGS, 1984 Zone 39N). Based on this classification method, six land cover classes were identified in the study area, namely urban built-up area, orchards, Irrigated agriculture land, dry farming, water, and wasteland. Based on Kappa index calculation the land use maps for 1984, 2014 was assessed and validated at 90.4%, and 87.6%, respectively. Finally, CA-Markov Chain Model has been used for simulation probable future LULC changes and expansion of Hamadan city by 2024. Flow chart of research method steps are shown in Fig. 2.

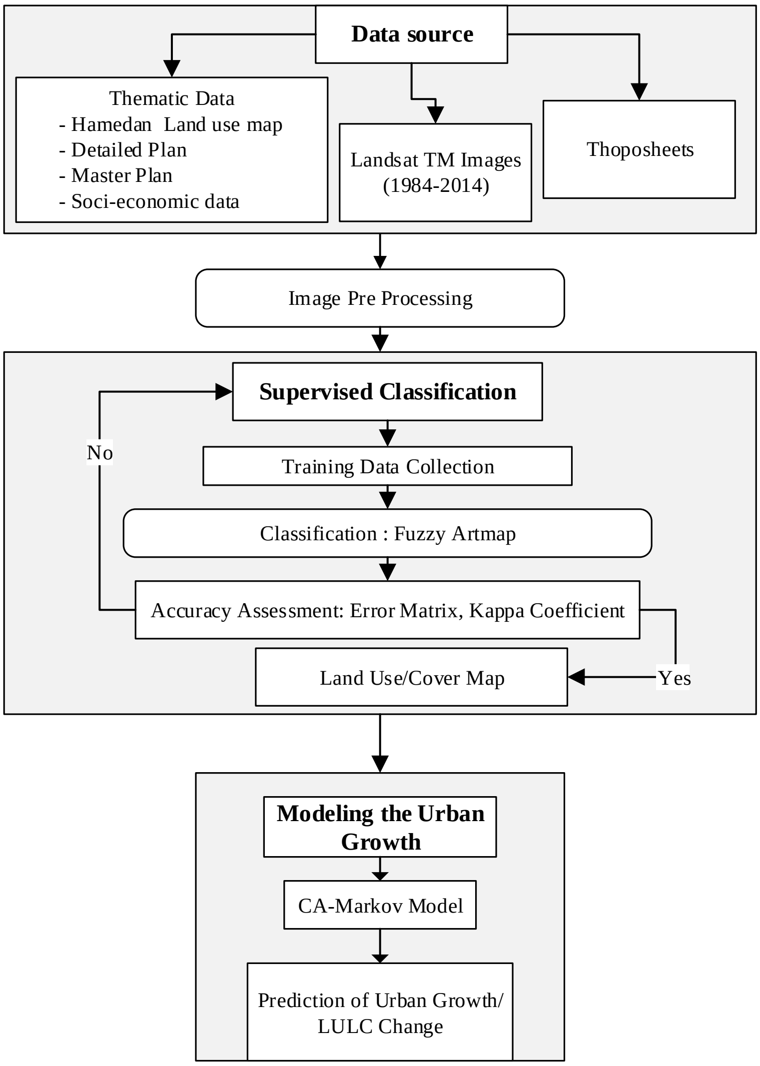

Fig. 2. Flow chart of research method steps

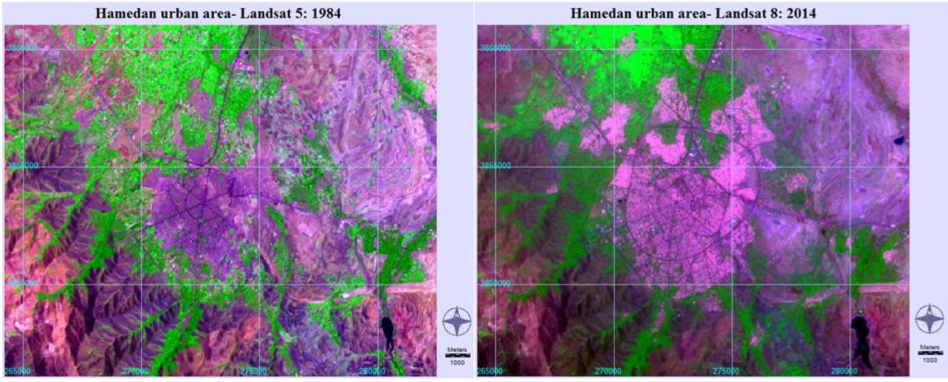

Fig. 3. Satellite imagery of Landsat for study area in 1984 and 2014

Table 1. Details of used satellite imageries

S. No.	Satellites	Sensors	Data	Resolution
1	Landsat 5	TM	1984	30m
2	Landsat 8	OLI	2014	30m

3. Results and discussion

3.1. Land use/cover change and urban sprawl

This study used post-classification change detection approach to change detection in the study area (Liu and Zhou, 2004). It's based on the comparison of independently classified satellite images of the same study area acquired during two different time periods (Serra et al., 2003). The analysis of land use changes revealed that built-up area of Hamadan city has increased almost threefold and changed from 2266.74 hectare in 1984 to 6004 hectare in 2014. The land cover categories of the study area for 1984 is shown in Fig. 4, while the land cover map of the Hamadan for 2014 is given in Fig. 5. The major drivers of urbanization in this duration could be related with Islamic Revelation in 1979 that led to a dramatic baby boom and rural-urban migration. This trend, not only change the land cover of region but also integrated many of former villages to the urban area. Table 2 and 3 gives the statistical results of LULC change. In contrary to build up, large amount of agriculture land has decreased and greater than 18571ha of irrigated agricultural lands has converted to build up areas (Table 2, 3). The irrigated agricultural lands for 1984 was 5787.81ha which decreased to 3557.61ha by the year 2014. The orchards and dry farming land have not undergone dramatic change because the majority of adjust land to build environment of Hamadan city was irrigated agricultural lands. The over the period, in general, 3199.5 hectares of orchards, irrigated and irrigated agricultural lands are lost due to urban expansion. The waste land has also decreased while the water body increased. A cross-tabulation that shows the changes in land use/cover by classes included in the study and are shown in Fig. 5 and Table 3. According to the cross-tabulation (Table, 3), irrigated agriculture lands was converted primarily to built up area and orchards and, partly, to dry farming. Although, Shannon's entropy may be an efficient tool for measuring urban sprawl, but it is only based on compactness or dispersion (Yeh and Li, 1997) and cannot integrate other components and indicators of sprawling such as longer commutes, car dependency and land use patterns and etc. Accordingly, this paper investigates Hamadan sprawling through reviewing the changes of these indicators over the time.The study of various historical documents reveals that like most other traditional cities the spatial proportion and the distances of constituting elements of city were based on human scale and the mobility pattern was pedestrian-oriented (Mahriar, 1989; Hamadani, 1999). The city was reasonably compact and the land use was mixed. Two distinct pattern has been shaped in the old neighborhoods: Circular (Golpa, Varmaz-yar, Haji Mahaleh) and linear (Koolanj, Bakhtiari). All the neighborhoods had public facilities such as mosque, public bath, butcher, bakery, convenience stores (Hamadani, 1999). After 1920 and regime change in Iran, gradually motorized vehicles substitute the camel or horse-driven vehicles. In addition, the hasty growth of population (about 5 percent for decades) inevitably induces spatial growth of urban areas. Inspiring from Haussmann's actions in Paris a century ago, the government intervene to manage the changes and paved the way for car penetration in downtown of Hamadan city (Marjan Consultant Engineers, 1968). A German architect named Carl Friesch was instrumental for new planning at that time, establishing six radial streets in city center and an unfinished circular road around it (Marjan Consultant Engineers, 1968). From then on, the new developments, including thriving service and commercial uses settled gradually along these streets, abandoning old neighborhood centers. Still up to 1960's the dominant pattern of the city was compact and mixed land use and the mobility was based on bicycles and walking (Marjan Consultant Engineers, 1968). However, six low-density new towns were developed outside the city boundaries in 1970s, and leading to loss of agriculture land and more car-dependent travels (Mojda Consultant Engineers et al, 1988).After the Islamic Revolution in 1979, the previous development pattern was continued even with more vigor and numerous new low-density residential estates in the urban fringe. The analyzing of recent Hamadan's development plans indicated that between 1966- 2011 the city density reduced from 216 persons per hectare to 66 people in 2011, and allocated lands to the transport infrastructure increased approximately 5.5 times (Mojda Consultant Engineers et al, 1988; Rahpuyan Consultant Engineers, 2008; Tarh & Tadvin Consultant Engineers, 2002). Hamadan's "Detailed plans" was developed in 2002 and based on approximately 7252 hectares added to administrative boundaries. This boundary covers greater than 3580 ha of the irrigated agriculture land and orchards. Detail plan has allowed construction and new development in those lands and result in threatening the socio-economic and ecological sustainability. While, currently, downtown covers only 3.2 percent of the total area, but more than 85% of commercial land uses situated in downtown (Tarh & Tadvin Consultant Engineers, 2002; Mojda Consultant Engineers et al., 1988). This trend will continue because in proposed land use in detailed plan, commercial land uses must develop in the downtown. However, many of the new development such as Alvand town, Shahid Madani town, Shahid Beheshti town situated in the best agriculture lands and haven't basic facilities and services. This growth pattern along with monocentric structure, road capacity expansion and new roads not only increased the land demand but also led to more and longer commute trip distances, traffic congestion, higher accident and pollutions level. It's also led to limited access for pedestrians and cycling and made transit service unviable or inefficient in most urban areas. Although the number of public transport lines increased from 19 in 1998 to 33 in 2008 but its speed decreased from 42 km/h in 1363 to 15 km/h in 1387 (Rahpuyan Consultant Engineers, 2008; Tarh and Tadvin Consultant Engineers, 2002). An auto-dominated transportation system has dramatically increased private car ownership. The percentage of car ownership has increased from 12% in 1984 to 56% in 2008 (Marjan Consultant Engineers, 1968). In recent years we witnessed big shopping centers and a single use development such as "Car City", "Furniture Market" and contraction of highways and huge overpass and underpass will continue. Without more doubt, we can argue that this growth pattern is urban sprawl.

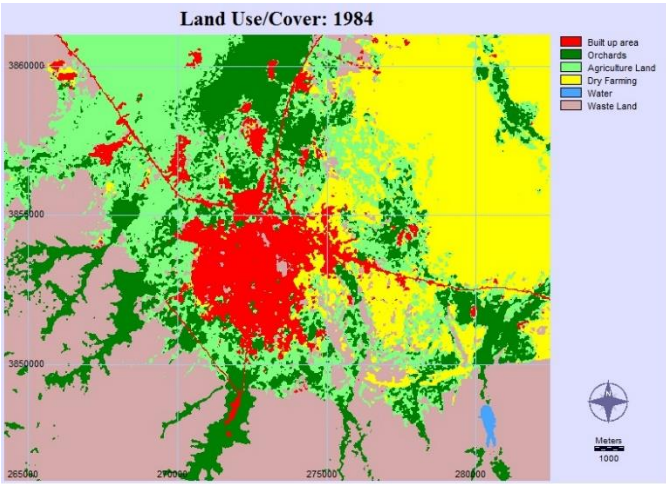

Fig. 4. Land use/cover classification maps of the Hamadan city in 1984

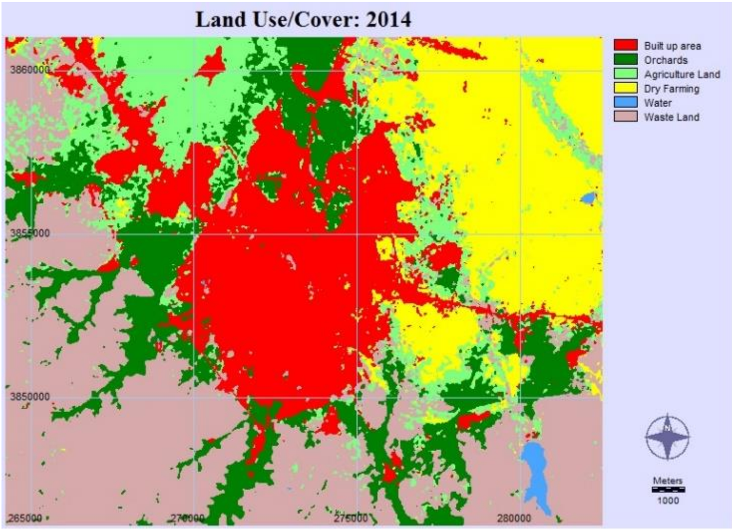

Fig. 5. Land use/cover classification maps of the Hamadan city in 2014

Table 2. The statistics of land use/cover change in in study area (Ha)

Class	Land use/cover	1984		2014	
		Area(ha)	Area (%)	Area(ha)	Area (%)
1	Built up area	2266.74	8.3	6004.8	22.0
2	Orchards	4495.32	16.4	4171.32	15.3
3	Irrigated Agriculture land	5787.81	21.2	3557.61	13.0
4	Dry farming	5427.09	19.9	4782.24	17.5
5	Water	46.17	0.2	119.79	0.4
6	Waste land	9317.07	34.1	8704.44	31.8
	Total	27340.2	100.0	27340.2	100.0

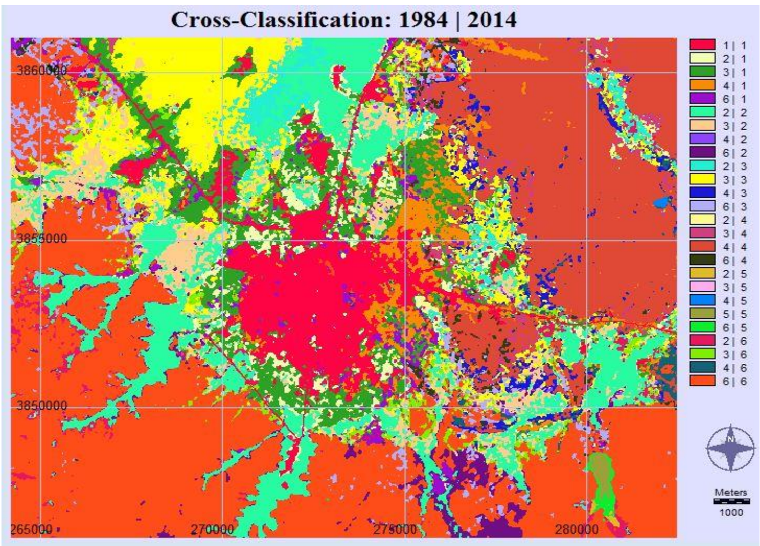

Fig. 6. Cross-tabulation of lands use change from 1984 to 2014

Table 3. Cross-tabulation of lands use change from 1984 to 2014 (Ha)

Class	1	2	3	4	5	6	Total 1984
1	2266.74	0	0	0	0	0	2266.74
2	680.94	2611.62	667.89	83.88	12.78	438.21	4495.32
3	1857.51	1084.41	1977.03	424.71	0.99	443.16	5787.81
4	764.91	33.84	371.25	4100.85	9.27	146.97	5427.09
5	0	0	0	0	46.17	0	46.17
6	434.7	441.45	541.44	172.8	50.58	7676.1	9317.07
Total 2014	6004.8	4171.32	3557.61	4782.24	119.79	8704.44	27340.2

3.2. Urban land use modeling and urban expansion prediction

Predictions of future land use change can improve our understanding of the status of urban growth and protected areas, making it possible to identify potential threats, intervention points and conservation opportunities (Pressey et al., 2007; Fleishman, 2011, Davis and Hansen, 2011). This paper employed a combination of Markov chain Model and Cellular Automaton approach to simulate future land use changes and urban growth using IDRISI software package. Markov Chain model is a stochastic process which controls temporal dynamic among the land cover classes using transition probabilities. It assumes that the state at some point in the future (t+1) can be identified as a function of the current state (t) (Balzter, 2000; Iacono et al., 2012). The main weaknesses of Markov Chain model are lacking of capability to simulate the changes in spatial distribution (Ye and Bai, 2008; Sang et al., 2011). Cellular Automaton largely has solved this deficiency by adding a spatial dimension to the Markov chain model. Thus, Combination of Markov chain and Cellular Automaton provide a powerful tool to model and simulate both spatio-temporal land use change (Kamusoko et al., 2009; Fan et al., 2008), particularly in cities where planners and policy makers have limited access to reliable socio-economic and historical data (Zhang et al., 2011; Fan et al., 2008). This hybrid approach utilizes a contiguity filter which is determined by the user. This paper has employed a filter 5 x 5 for modeling purposes. This filter was used on the suitability images for each LULC classes. LCLU change modeling was performed for the years 2014 to 2024 and the findings are shown in Fig. 7. 8. and Table 4, 5. Generally, the results of the simulation revealed that by 2024, nearly 1112 ha of non-built area will be converted to built-up area. In other words, this unsustainable trend in Hamadan will continue by 2024, destroy 1060.40 hectares of orchards and agricultural land (Table 5). Without more doubt, the current trend would have a considerable impact on the quality and quantity of water and surrounding ecosystems.

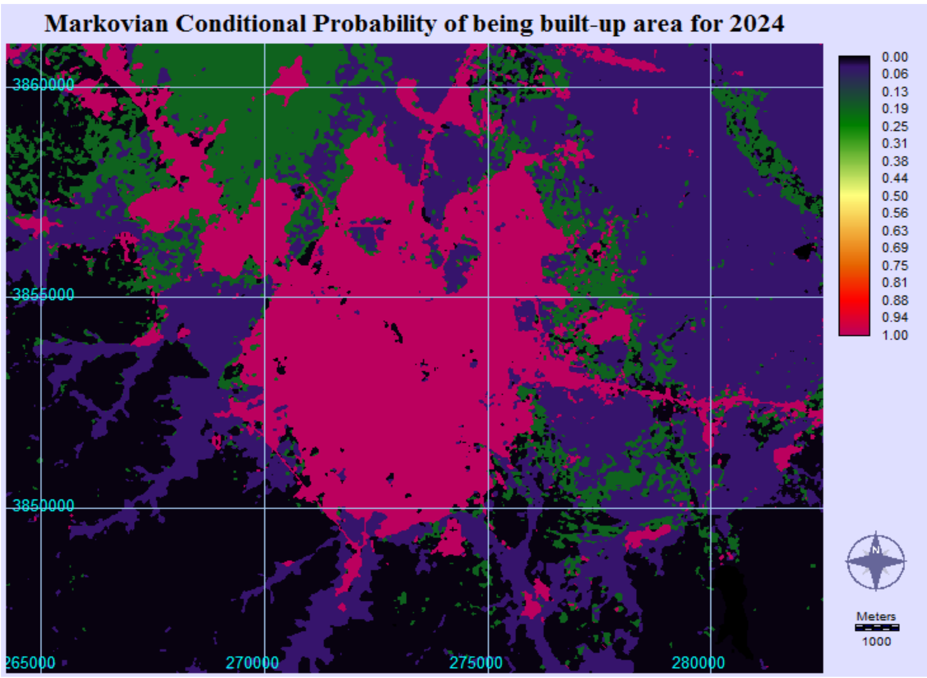

Fig. 7. The Probability of transition class of LULC by 2024 obtained by Markov Chain

Table 4. The Probability of transition class of LULC by 2024 obtained by Markov Chain (percent)

Class	1	2	3	4	5	6
1	100	0	0	0	0	0
2	4.25	76.80	13.85	0.19	0.12	4.79
3	18.95	17.82	53.21	5.66	0	4.36
4	4.22	0	5.09	89.74	0.06	0.89
5	0	0	0	0	1	0
6	0.62	1.91	3.87	0.57	0.02	92.82

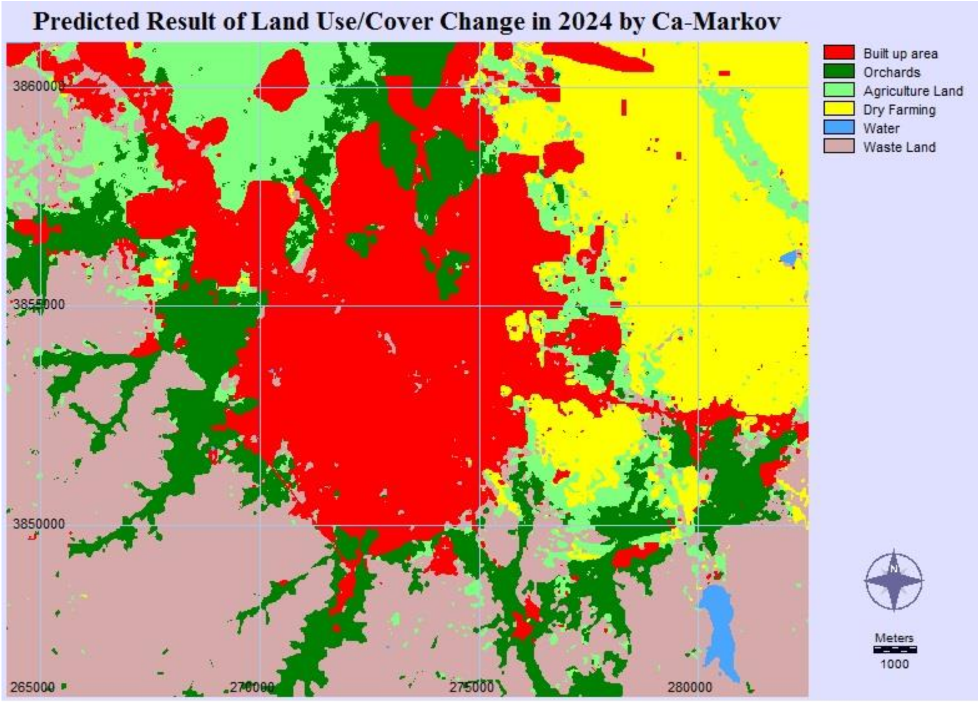

Fig. 8. Land use/cover prediction in urban area by 2024 through CA-Markov Chain

Table 5. The transition area of each class of LULC by 2024 through CA-Markov (Ha)

Class	1	2	3	4	5	6	Total 2014
1	6004.8	0	0	0	0	0	6004.8
2	148.23	3967.29	27.09	0	0	28.71	4171.32
3	711.45	41.94	2802.96	0.81	0.45	0	3557.61
4	200.7	0	37.08	4544.1	0.36	0	4782.24
5	0	0	0	0	119.79	0	119.79
6	46.62	0	184.23	7.56	0	8466.03	8704.44
Total 2024	7111.8	4009.23	3051.36	4552.47	120.6	8494.74	27340.2

4. Conclusion

Global food security due to rapid urbanization, environmental degradation, climate change and unsustainable global food system has become one of the most key challenges of global development. In addition to these, especially in developing countries like Iran, urban sprawl threatens the urban agriculture and food security. Hamadan city in one of such cities which experienced rapid population growth and spatial expansion over the last few decades. This paper was carried out on spatiotemporal change analysis in the Hamadan city via the GIS and remote sensing tools. This approach is valuable and effective as well as one of the most common change detection approaches. The findings of the analysis indicate that urban sprawl during 1984-2014 led to a loss of frailest urban and peri-urban agriculture lands and it is expected this unsustainable trend will be continued up to 2024. Fig. 9 and Table 6 are shown the overview of land use change and total area of built up class in 1984, 2014, 2024. This trends not only threatens food security but also will lead to excessive car dependence, poverty increase, loss of local jobs, more pollutions and result in unsustainable development. The policies relying on compact city approach, establishing green belt and directing the new growth demand to satellite towns should be advocated.

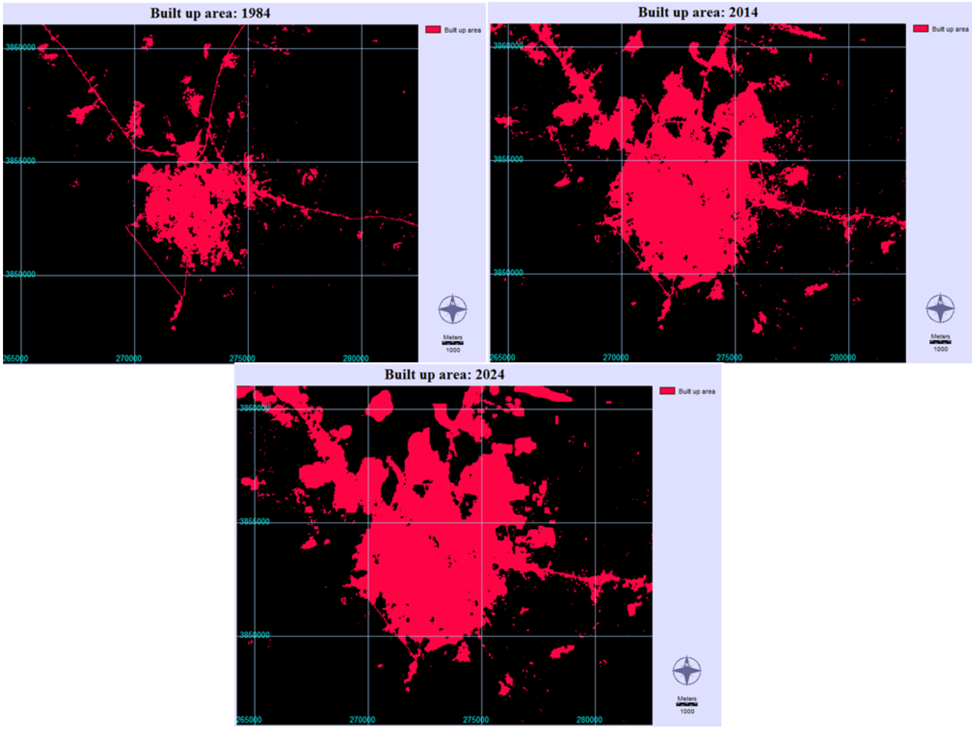

Fig. 9. Built up area in 1984, 2014 and 2024

Table 6. Summary of built up area in study area (Ha)

Land use/cover	1984	2014	2024
Built up area	2266.74	6004.8	7111.8

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