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Research Article

Spatio-temporal Analysis of Urban Expansion on Farmland and Its Impact on the Agricultural Land Use of Mardan City, Pakistan

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Abstract: In this study GIS and remote sensing techniques have been applied for assessing the increasing trend of farmland conversion of Mardan city, Pakistan into impervious surfaces. The study area was a part of the fertile and productive land of Peshawar vale. The analysis was undertaken using Landsat 30 m of 1990 and SPOT 2.5 m of 2010. The datasets were interpreted with Maximum Likelihood supervised classification approach in ArcGIS environment. In addition, ground verification and parcel data for the test years were obtained from the Land and Revenue Department, Mardan. The results were classified into major land use categories of built-up area, farmland and cultivable waste. The analysis revealed that rapid increase in population has resulted in haphazard urban expansion particularly after 1990. During the study period, the built-up area has been doubled from 30% of the total city area in 1990 to over 63% in 2010, thereby has doubled the impervious surfaces. Consequently, the prime agricultural land has shrunk from 1,339 ha (42%) to 1,109 ha (35%) during the two decades. Similarly, the share of cultivable waste was decreased from 827 ha (26%) in 1990 to 16 ha (0.5%) in 2010. It was found that the increasing demand for housing and other infrastructure was fulfilled by conversion of fertile agricultural and cultivable waste. The study further revealed that Mardan city is expanding haphazardly in all directions without strategic land use regulations and planning and thus is posing serious threats to the fragile environment.

Keywords: GIS, remote sensing, land use, cereal production, Mardan city

1. INTRODUCTION

Globally, the ongoing urbanization is considered to be one of the foremost threats for sustaining urban ecosystems [1]. Expansion of cities has been continuous for many decades [2]. This expansion particularly in the developing world is taking place at the expense of prime agricultural land [3, 4]. According to the United Nations [5] by the year 2050 the proportion of urban population will rise to 66% and 90% of the projected increase would occur in developing countries. It has also been predicted that most of urban growth will occur in small cities and towns.

Currently, a little over 1% of the earth surface is occupied by urban areas [6]. One of such emerging challenges is the conversion of agricultural land into built environment [7]. The farmland once lost has irreversible impacts on urban landscape and food security [8]. This in turn also influences human health, quality of life and natural environment [9, 10]. Parallel to this, the increasing built-up area at the cost of farmland is responsible for the high degree of impervious surfaces [11, 12]. Breuste [13] has identified numerous negative impacts of urban infrastructure, which include accelerating surface runoff, reducing recharge of underground aquifers and multiplying carbon footprints [14, 15].

Like other developing countries, in Pakistan the urban population has been increasing at a rapid pace and the World Bank has estimated that half of the country's total population will become urban by the year 2020 [16]. By way of increasing

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urban population, the prime agriculture land is being encroached by housing, infrastructure, industrial, educational and commercial uses [17, 18]. Change in urban land uses takes place either by reorganization of land uses or by outward expansion of urban areas [19]. In the reorganization processes, patches of urban agricultural land inside the city get converted into built up areas, whereas in the process of urban expansion, the loss of prime agricultural land in the suburban is irreversibly influenced and the food supply chain get affected adversely [20]. This situation is being aggravated by the rapid rate of farmland conversion into built-up areas [21].

This study focused on Mardan city, Pakistan. Geographically, Mardan city stretches from 34° 9' 4″ to 34°13' 21″ N latitude and 72° 3' 11″ to 72° 14' 48″ E longitude covering an area of 32 sq km (Fig. 1). It is located 64 km away from Peshawar, the provincial capital of Khyber Pakhtunkhwa (KP) and 148 km west of Islamabad, the federal capital of Pakistan. In the present study, GIS and remote sensing techniques were employed to detect changes in the land use pattern. Within Khyber Pakhtunkhwa province, Mardan is the 2nd largest and fastest growing city after capital city district Peshawar. During the past few decades, there has been significant urban expansion over the peri-urban agricultural land of this city. Likewise, the construction of District Head-quarters Hospital, Government Postgraduate College Mardan, Premier Sugar Mills Mardan and Tobacco industry were the other major developments that have attracted a large population to settle in the proximity to of old Mardan city. Since the 1990s, Mardan city has experienced a rapid growth both in terms of population and spatial extent [18]. The urban area has expanded on the fringes at the cost of prime agricultural and waste land. The rich agricultural products in neighborhood of the city have made it a thriving market and have enabled development of agro-based industries in the new vicinities. In addition, there are several bazaars, markets, shopping malls and plazas of commercial importance. A number of new markets and plazas are also under construction on the prime agricultural land. Besides serving Mardan district, the city is considered as one of the most important trade centers for the surrounding districts of KP province [18]. Mardan city is also characterized by complex urban and peri-urban landscapes, with a combination of diverse land uses at varying spatial scales. During the past two decades (i.e., 1990-2010), rapid urban expansion took place over the farmland. Such conversion of land use was reported more seriously at the city periphery as against rural section of district Mardan and so for no empirical research has been carried out on this aspect.

A massive growth in Mardan city had started after 1990 and the city authorities failed to exercise development control during this expansion. The process continued and it is imperative to monitor and quantify the increasing trend of farmland conversion into built-up area and devise strategies for mitigating the adverse impact. In 1901, urban population of Mardan City was mere 4000, which grew and rose to 77,932 in 1961. By the year 1998, the population further increased to 246,000, with the current growth rate the estimated population of the city was 402391 in 2015, and would reach to 512,778 in 2030. With the advancement in geoinformatics, the spatio-temporal satellite images are available to monitor and quantify the changes in land use with time. The remotely sensed data are being increasingly used as an important tool for detecting farmland conversion into built environment [19, 20, 21, 22, 23]. In this study an attempt has been made to apply multi-temporal images while analyzing the urban land use pattern in and around Mardan city, which is expanding rapidly with serious implications on for the peri-urban farmland.

2. MATERIALS AND METHODS

The data were collected both from primary and secondary sources. The primary data includes satellite imageries (Landsat 30 m for the year 1990 and Spot 2.5 m for 2010) of Mardan city were obtained from SUPARCO office, Peshawar (Fig.

2). In order to investigate the causes of urban expansion focused group discussions (FGDs) were conducted with the officials of urban authorities, District Revenue Office, politicians, landlords, elderly people and estate agents. In addition to this, secondary data were obtained from related Government departments. Similarly, maps of Mardan city were obtained from Mardan municipal committee, whereas population data were acquired from the Population Census Organization of Pakistan. Land use and crops statistics were obtained from the Bureau of Statistics and land records of the revenue office, Mardan.

The satellite images enabled us to quantify the changes in land use and soil sealing over the last two decades. Two images (Landsat 30 m for the year 1990 and Spot 2.5 m for 2010) of 20 years apart were chosen. Image classification technique helped to extract information about the land use and land cover type from the remotely sensed data. Both supervised and unsupervised classification approaches were used for processing the satellite images. Supervised classification is considered as an efficient method used to deal with the satellite images. Temporal images of Mardan city were processed using Supervised Maximum Likelihood Classified Algorithm technique in ArcGISenvironment. A total of 150 training samples (signatures) were generated for every land use class, i.e., built-up, agricultural land, cultivable waste and water bodies.With the help of GPS, ground verification was done for ground truthing and sample verification. This helped in processing the data for spatio-temporal analysis of urban expansion in the peri-urban environment. The areas under different land uses were then quantified.

The analyzed data were checked for quantitative and qualitative accuracy assessment for the final classified images of 1990 and 2010. The qualitative assessment is based on visual interpretation techniques and the same was tallied with the open source Google Earth, whereas, the

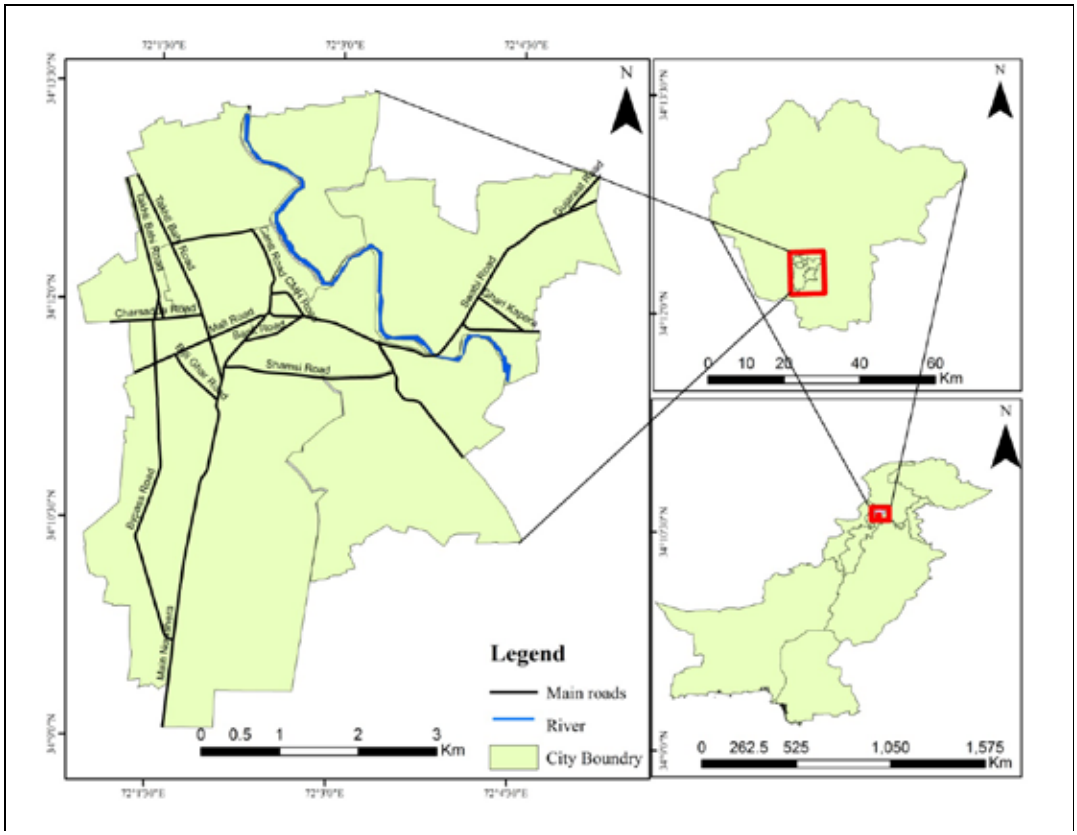

Fig. 1. Location of the study area, in Mardan city, KP, Pakistan

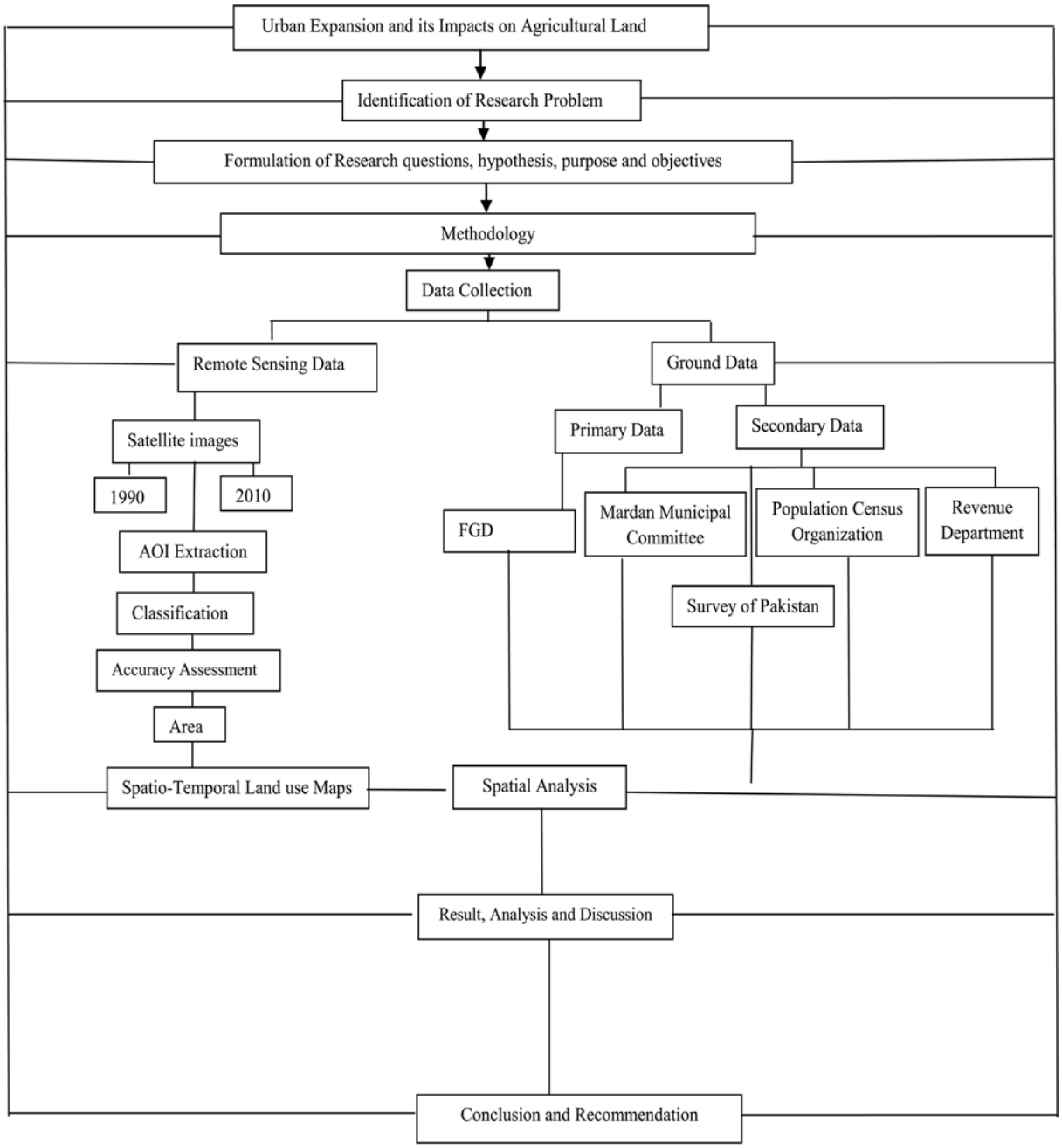

Fig. 2. Research process.

quantitative assessment was carried out through a standard technique of error matrix [24]. A stratified random sampling approach was applied to validate samples and the resultant thematic layer classes. Approximately 50 reference points were then generated for each land use class. Most of the sample reference points were checked during field surveys. Overall accuracy, user's accuracy, producer's accuracy and Kappa coefficient were calculated for 1990 and 2010 classified maps. The resultant maps met the overall minimum 85% accuracy as specified by the Anderson classification scheme [25]. As a result the quantified data for all the land use changes between 1990 and 2010 were compiled and tabulated. The land use maps of Mardan city for 1990 and 2010 were generated, which helped in comparing the changes in land use pattern and the growing pace of urban expansion over the farmlands.

3. RESULTS AND DISCUSSION

In order to achieve the objective, the present study focused on digging out the expansion of built-up area and its impacts on farmland and food production. The analysis revealed that in Mardan city population growth over the time period has caused great changes in the available land use. The demand for new houses increased with increasing population and growing income. The population increase has mainly been due to both natural increase and rural to urban migration. People from the surrounding areas have migrated to the city in search of better employment opportunities, education and health facilities.

The spatio-temporal dynamics in land use from 1990 to 2010 were extracted through the analysis of multi-spectral Landsat images. Rapid growth in population and subsequent urbanization is the main cause of enormous increase in land use changes in Mardan city. The overall land use changes that took place in 1990 and 2010 (Table 1; Fig. 3a, 3b). The urban built-up area that has increased substantially during the last two decades has been illustrated (Fig. 4). During the study period, Mardan city has undergone substantial expansion. Both visual and change detection maps revealed that most of the farmland in Mardan city has been consumed by residential, commercial and other uses indicating that arable soil has been converted to impervious surfaces. Likewise, in 1990 a big chunk of waste land was converted for such uses. The conversion of the food basket land and cultivable waste land into different land uses has been discerns (Fig. 5).

3.1 Status of Land Use/ Land Cover

In this study, a post-classification detection method was applied. The change metrics of Weng [26] has been used to quantify the extent of land utilization in 1990 and 2010 and the resultant gains and losses in each category were analyzed. The analysis revealed that in 1990 approximately 30% area of Mardan City (953 ha) was under built environment, 42% (1,339 ha) under agricultural land and the rest 26% (827 ha) was waste land (Table 1). In addition to this, 1.1% area (35 ha) was occupied by river Kalpani. During the year 2010, the built-up area was 63% (1994 ha), agricultural land 35% (1,109 ha), and cultivable waste 0.5% (16 ha), whereas area under water bodies remained unchanged during the study period (Table 1). This expansion of built-up area had engulfed the surrounding farmland, whereas the waste land has increased. With the rapid growth of population, the housing demands also increased and the nearby cropped land was converted into built-up environment. Along with land use conversion, the land value within the city limits has escalated several times.

Table 1 Mardan city: Land use change, 1990-2010.

Land use	1990		2010		Change 1990-2010	
	Area (ha)	Percent Share	Area (ha)	Percent Share	Change in Area (ha)	Percent change (%)
Built-up area			407.5	12.9		
Commercial	953	30	85	2.7	1041.5	33
Residential			1502	47		
Agricultural land	1339.1	42.4	1108.8	35.1	-230.3	-7.3
Cultivable waste	827.4	26.2	16.4	0.5	-811	-25
River	35	1.1	35	1.1	0	0
Total	3154.7	100	3154.7	100		

Source: LANDSAT 1990, SPOT 2010

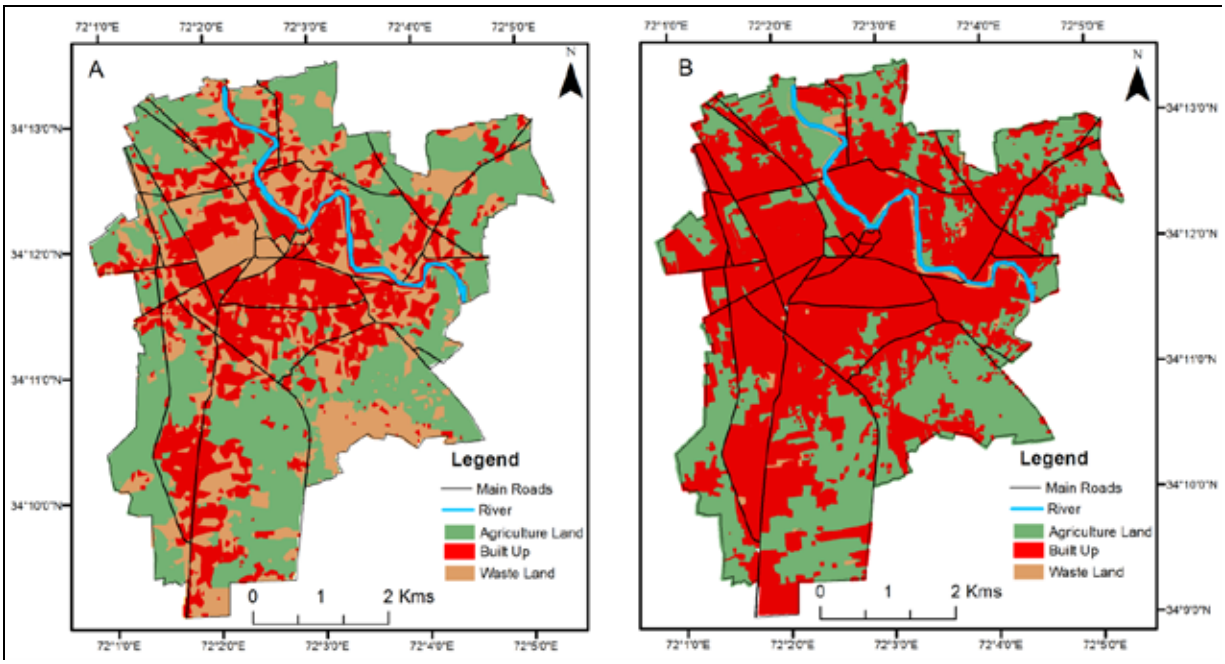

Fig. 3. Mardan city: Spatial distribution of land use, 1990-2010: (a) Land use in 1990; (b) Land use in 2010.

3.2 Spatio-temporal Analysis of Land Use/ Land Cover

The analysis revealed that, during the last two decades, both negative and positive changes have occurred in the land use and land cover pattern of Mardan City (Table 1; Fig. 3). The built environment has more than doubled as it has increased from 953 ha in 1990 to 1994 ha in 2010. The increase in built up area accounts for 52% of the total area. This increase in built-up environment was occurred as a result of rapid growth in urban population and creation of better transport facilities and other amenities within the city. As a result, the demand for housing has increased, which allowed the people to construct new housing units on the available farmland haphazardly without taking into consideration proper planning and management. Transport infrastructure has become another determining factor in expansion of Mardan city and accessibility from newly built-up areas. Anjum and Hameed [27] noted that those housing schemes were more successful which were located close to the existing built-up areas. Perhaps these provided a better sense of security in a new scheme to a potential dwelling owner. This appears to be one of the reasons for the rapid expansion which took place in the existing villages which were eventually engulfed by the city and the agricultural land was converted into residential areas.

The comparative analysis revealed that a gradual decrease has occurred in the farmland from 1,339 ha in 1990 to 1,109 ha in 2010, which is 17% of the total area. The main reason behind this decline in cropped land was the increase in land prices which encouraged the poor rural households to sell their land at higher prices. Having small parcels of land, they could not meet their family needs; therefore, with better price offers they sold their farmlands and opted out for alternative sources of income. Similarly, the cultivable waste land has decreased drastically, from 827 ha in 1990 to mere 16 ha in 2010. Most of this waste land has been transformed into built-up areas. However, the area under water bodies remained same during the two decades (1990-2010).

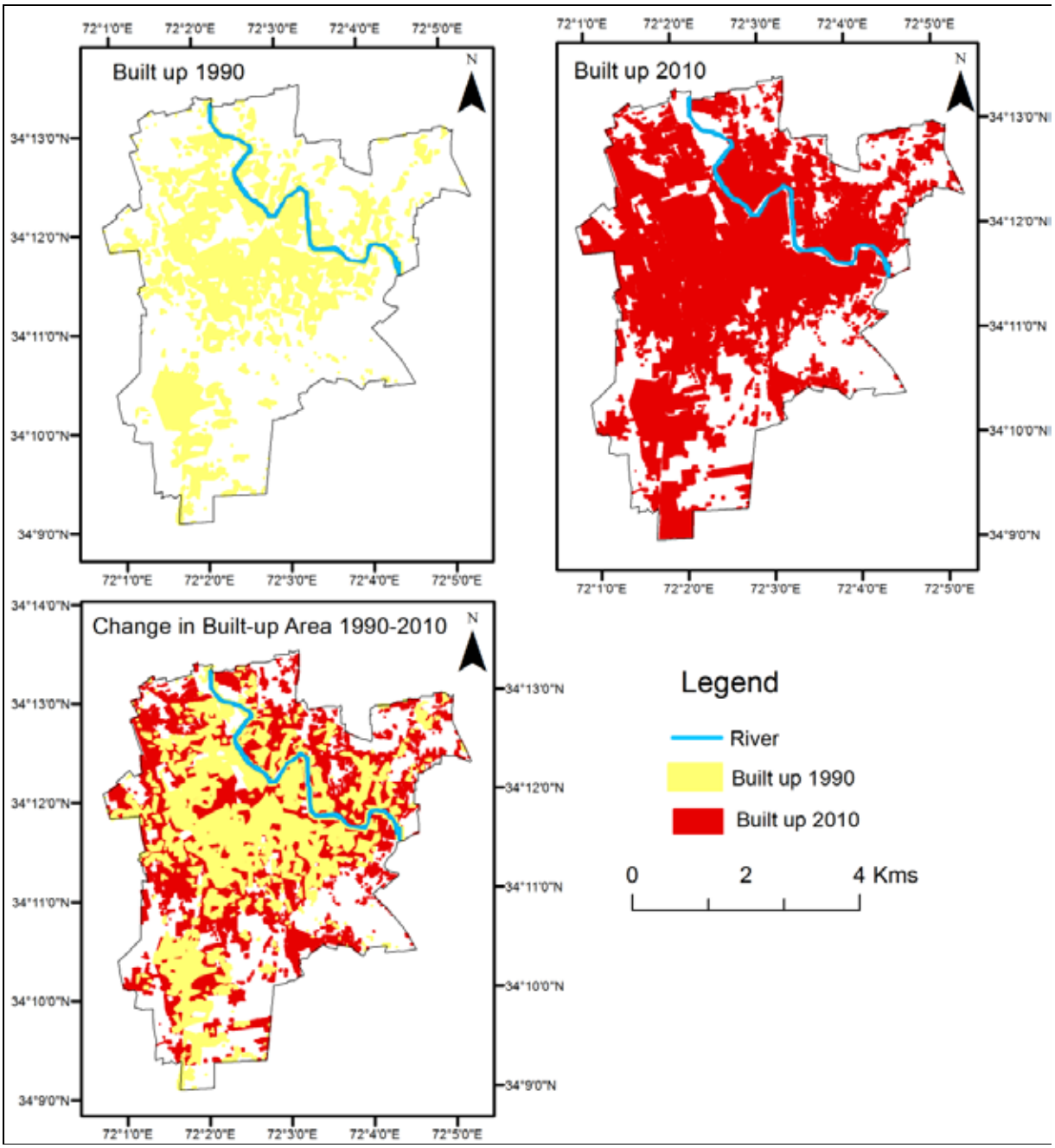

Fig. 4. Mardan city: Spatial growth of built-up area, 1990-2010.

To understand land encroachment in different land use categories, a change detection matrix (Table 2; Fig. 5) was prepared which revealed that during the two decades (1990-2010), the farmland within the city limits has been gradually transformed. The highlights of these transformations in Mardan City over 1990-2010 period are given in Table 2. The largest consumer of farmland was built-up environments. A total 613 hectare of waste land was lost to built-up uses over the study period of 1990-2010. This means that 52% of the newly built environment was developed over the waste land. However, almost 33% of farmland was also lost to built-up area during this period. Nevertheless, there was also gain in the agricultural land mainly by bringing around 141 hectares of cultivable waste land under plough. The spatial pattern of these changes has been shown in Fig. 5.

Table 2 Farmland conversion in Mardan city, 1990-2010.

Land use change 1990-2010	Area lost (hectares)	Percent of total loss
Waste Land to Built-up area	613	54.5
Farmland to Built-up area	371	33
Waste Land to Farmland	141	12.5
Total	**1125**	**100**

Source: LANDSAT 1990, SPOT 2010.

3.3 Trend of Cereal Production in Mardan City since 1990

The food production has seen marked growth during the last half-century, allowing a dramatic decline in the percentage of hungry people across the world, in spite of doubling of the total population [28]. However, more than one out of seven people today still do not have access to balanced food [29]. Currently, the world is facing a new set of intersecting challenges. The global population will continue to increase and it is estimated that approximately 9 billion people will be living on this tiny planet by 2050. With

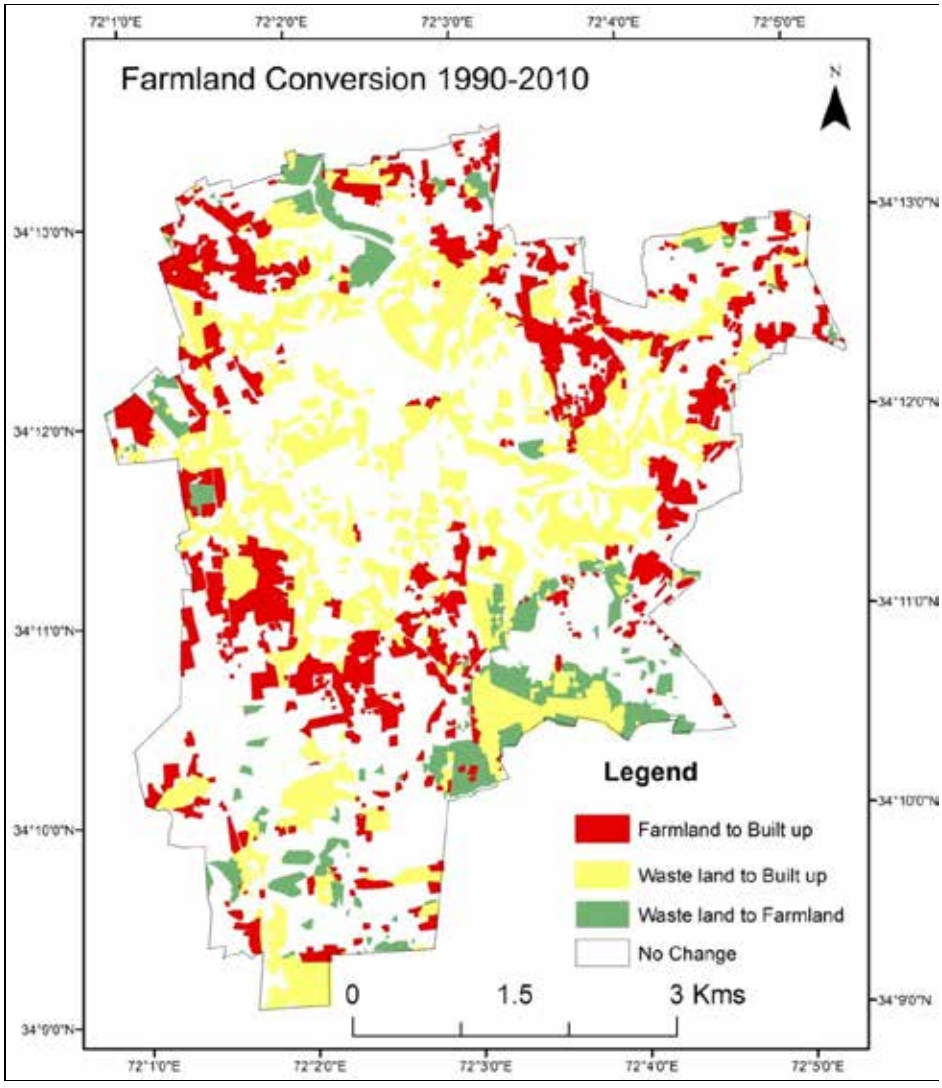

Fig. 5. Mardan city: Farmland conversion, 1990-2010.

increase in population, the demand of food consumption has increased, which has put immense pressure on the food supply chain. The food producers at the same time are experiencing tough competition for the land, water and energy, and are trying to minimize the negative impacts of food production on the environment [29]. Therefore, the urban food production is generally under estimated. Mouget [30] has conservatively estimated that 15-20% of the world food is produced in urban areas. According to Nelson [31], approximately 200 million urban dwellers are engaged in urban farming and providing food to almost 800 million people. Case studies point out significant degree of self-sufficiency in fresh vegetable, poultry production and other animal byproducts.

In south Asia, the population tripled from 588 million in 1990 to 1621 million in 2010. During the same period, with the increasing population, there is decline in per capita farmland. Kumar et al. (2012) found that during 1980 to 2010, in Bangladesh per capita agricultural land decreased from 0.11 ha to 0.05 ha, in India 0.23 to 0.13 ha, in Nepal 0.15 to 0.08 ha and in Pakistan 0.24 to 0.12 ha. It is predicted that by the year 2015, South Asian population will escalate to 2.2 billion people and their cereal requirement will rise from 241 million tons in 2000 to 476 million tons in 2025 [32].

According to Veni and Alivelu [33] in India the rapid growth in population has put immense pressure on the farmland, which has decreased the production of food grains crops. The land under built environment has been doubled over a period of past 50 year, which was 9.36 million hectares in 1951 and climbed to 22.97 million hectares in 2001 [34]. Tan et al. [35] identified a dramatic decreased in per capita farmland during 1998-2009 in Beijing from 0.05 to 0.03 ha, Zhejiang 0.06 to 0.04 ha, Shanghai 0.06 to 0.02 ha, and Guangdong 0.06 to 0.02 ha. It is mainly due to conversion of food basket land into built-up uses. Rauch and Morrison [36] pointed out that about 922 ha of fertile agricultural land in District Sleman (Indonesia) has been converted into housing complexes, with the conversion rate of about 33% (3.3% annually) during 10 year. Due to conversion of arable land, there has been remarkable decrease in production of rice in districts of Sleman and Bantul.

Pakistan is a developing country. Here, agriculture is considered as the backbone of country's economy. Its rapidly growing population largely depends on agricultural sector. The country's growth rate has declined from over 3% in 1980 to 2.09% in 2010. With the existing growth rate, the estimated population will get doubled by the year 2050 [37]. However the availability of per capita cereals has increased from 120 kilograms to 137 kilograms from 1961 to 1991, and then climbed to 154 kilograms in 2008-09.In spite of considerable improvements in food supply, the malnutrition is still a serious challenge in Pakistan [38].

Studies of urban encroachments of agriculture land and its impacts on food production in Pakistan have remained limited to large cities like Lahore or Peshawar. According to Zaman [39], in Lahore the production of wheat, maize, sugarcane, vegetables and fruit has been reduced and about 114,630 ha of cultivated land has been eaten up by built-up uses during 1987-2008. Samiullah [18] has studied the expansion of built-up area and its impacts on agricultural land in Peshawar City District and has stated that this district had lost most of its best agricultural land to urbanization. Residential land use was the largest consumer of arable land followed by the brick kilns during the period 1991-2009. Bhalli et al. [40] applied GIS and remote sensing technologies to monitor and assessed urban sprawl in Faisalabad, and pointed out that during the 30 years (1980-2010), there had been a rapid increase in the urban built environment. This expansion has taken place on the primary or fertile agricultural land in urban fringe and as a result the city area has doubled from 102 sq km in 1980 to 213 sq km in 2010 and, consequently, has drastically reduced the agricultural acreage.

In the Mardan study area, with the increase in population over the last two decades, the availability of per capita farmland has declined from 0.006 hectare in 1990 to 0.002 hectare in 2010. The per capita agricultural land in the city

limits will continue to decrease with continuing population growth. The Table 3 depicts the situation of food production in Mardan City. The yield per hectare has increased over the last 20 years. Also over the last two decades (1990-2010) the production of wheat has improved from 1,744 kg per hectare in 1990 to 2,104 kg per hectare in the year 2010. Likewise, the production of rice has increased from 1,538 kg to 1,890 kg, sugar cane from 39,987 kg to 48,550 kg per ha, maize from 1,918 kg to 3,324 kg and barley from 910 kg to 885 kg per hectare.

Table 3 Change in yield of major crops in Mardan city, 1990-2010.

Crops	Yield (kg/ha) 1990	Yield (kg/ ha)2010
Wheat	1744	2103
Rice	1538	1890
Sugar Cane	39987	48550
Maize	1918	3324
Barley	885	910

Source: Development Statistics of Khyber Pakhtunkhwa, 1990, 2010.

4. CONCLUSIONS

The present study demonstrated the effectiveness of remote sensing and Geographic InformationSystem as a tool in analyzing land use changes. The analysis revealed that Mardan city has experienced a rapid growth during the last two decades (1990-2010). The area under built environment has increased from 953 ha to 1,994 ha over the study period. The city has expanded in all directions over the peri-urban farmland. Most of this expansion is haphazard and unplanned mainly following ribbon sprawl along the roads and radiating out of the city. Over the period, the agricultural land has been lost to built-up area. The cultivable waste land which covered a big chunk (827 ha) in 1990 has been reduced to mere 16 ha in 2010. During 1990-2010 about 613 ha of cultivable waste land and 371 ha of farmland were lost to built-up uses. Though, there was also a gain in farmland, about 141 ha of cultivable waste land was transformed to farmland. Escalation in land value, housing demands, improvement in transport was the main factors responsible for the conversion of farmland into built-up areas. Consequently, the per capita farmland has been reduced, gradually. However, the production of cereal crops have been increased due to better irrigation facilities and utilization of improved type of seeds and application of fertilizers over the study period.

In order to sustainably utilize the urban land, the government must promote agriculture and encourage, establish and reinforce farmer organizations in Mardan city and or in peri-urban areas. Also, effective land use zoning may help to contain the urban encroachment over the farmland. The urban authorities may restrict construction on the available farmland. It could also develop alternate sites for development of new townships on the barren land. Monitoring urban expansion is also necessary to make the city's expansion is accordance with the urban planning standard. GIS and Remote Sensing techniques could be used to monitor urban expansion in and around Mardan city. The government should also initiate awareness programs on the negative implications of haphazard urban sprawl.

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