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RESEARCH

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Effects of urbanization on the resilience of the farming systems in peri-urban areas: A case study of Hyderabad, India

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Abstract

Background: Urbanization is a dynamic process with multifaceted effects on agriculture. While facilitating land use changes, it is also influencing market access, technical efficiency of farming, land prices, and regulatory frameworks. This study aims to understand the effects of urbanization on the resilience of the farming systems in the peri-urban areas of Hyderabad, India. *Methods*: The resilience of the farming systems is characterized by the three capacities of resilience i.e. robustness, adaptability, and transformability. Indicators were identified for the attributes that contribute to the capacities of resilience. For primary data collection, six focus group discussions were conducted followed by a household survey of 400 farm households in the blocks around Hyderabad. We use factor analysis to combine these indicators of resilience capacities into indexes. *Results*: Our findings suggest that urbanization has a mixed impact on the resilience of the farming systems. The farming system Diversified Cropping with Dairy is more robust while the farming system Diversified Cropping without Livestock is more adaptable and transformable as compared to the other farming systems in the study area. *Conclusion*: The indirect effects of urbanization, i.e., market effect and the technical efficiency effect contribute positively to the adaptability and transformability of the farming systems by facilitating market access, demand for high-value crops, access to infrastructure, and agricultural services. It directly affects the robustness of the farming systems negatively by constraining access to natural resources i.e. land and water.

Keywords: peri-urban, urbanization, farming systems, resilience

Introduction

Urbanization, which is fast-changing, context-specific, and a result of interconnected factors, is the outcome of the rise in urban population, urban expansion (i.e., reclassification of rural areas to peri-urban or urban), and migration from rural to urban areas (FAO *et al*., 2023). From 1975 to 2020, the city population in low-income countries grew to 300 million, which is expected to reach 700 million by 2070 (UN-Habitat, 2022). As cities grow rapidly, it is expected that almost seven out of ten people will live in urban areas by 2050 (FAO *et al*., 2023). While urbanization is transforming farming systems around the world through direct and indirect effects, its emergence as a global trend is connected with a variety of challenges and opportunities.

Land use change from farm to non-farm uses is a *direct effect* of urbanization. It is estimated that by 2030, 3.7% of global farmland will disappear due to urbanization (Deng *et al*., 2020). The loss of prime farmland correspondingly poses serious challenges to food security at local, regional, and global scales. However, the impact goes beyond the mere physical loss of land. Urbanization also brings productivity and production relocation challenges. According to (FAO *et al*., 2023), the loss of agricultural land near urban centers is coupled with a higher loss in productivity, estimated at 6–9% in Asia and Africa. This productivity loss surpasses the absolute loss of land due to the fertility of these lands and historically higher agricultural productivity has been found around cities. Furthermore, while in many countries agricultural production can be relocated, there could be regions, where limitations in arable and fertile land hinder this transition, raising concerns about long-term food security at the local scale.

The impact of urbanization on farming systems also goes beyond the simple conversion of farmland into urban areas. *Indirect effects* take shape across four distinct categories (Lopez *et al*., 1988):

REGULATORY EFFECTS

Regulatory changes may emerge, affecting land use policies, agricultural practices, and land ownership. These shifts can

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reshape the regulatory landscape of farming systems, potentially altering production dynamics. For example, Chen *et al*. (2018) highlighted the role of agricultural land use policies in causing farmland price distortions, land fragmentation, and agricultural production.

TECHNICAL EFFICIENCY EFFECTS

Transformation of landscapes necessitates adjustments in land, labor, capital, and material resource allocations impacting technical efficiencies. For example, in the case of many Asian and African cities, farmers in the surrounding areas have responded by turning to wastewater-irrigated agriculture (Gumma *et al*., 2011; Gyasi *et al*., 2014; Kuusaana and Eledi, 2015; Gumma *et al*., 2017), use of chemical inputs (Gyasi *et al*., 2014; Hussain and Hanisch, 2014) increasing the use of modern inputs (Steinhübel and von Cramon-Taubadel, 2021), use of groundwater (Gyasi *et al*., 2014; Youssef *et al*., 2020), changing cropping pattern (Hussain and Hanisch, 2014; Nguyen and Kim, 2019; Youssef *et al*., 2020), and livelihood diversification (Hussain and Hanisch, 2014; Nguyen and Kim, 2019).

SPECULATIVE EFFECTS

Urban expansion can create speculative pressures on land prices, causing fluctuations that influence land use decisions and potentially driving some agricultural activities to less urbanized areas. This can make farmers less responsive to what is happening in the market for crops. This is called the "impermanence syndrome," where farmers do not want to invest in machinery or farm systems because they might sell the land soon (Lopez *et al*., 1988).

MARKET EFFECTS

Urbanization influences consumer preferences, necessitating shifts in the types and quantities of agricultural products demanded (Rao *et al*., 2006; Birthal *et al*., 2007; IFPRI, 2017). Additionally, urban centers can become key markets, changing the dynamics of distribution and supply chains. Urbanization also brings farmers closer to their markets and thus reduces transportation costs. The locational advantage also opens new marketing avenues that can make farmers more competitive (Filippini *et al*., 2016; IFPRI, 2017, Hazell, 2019).

Urbanization and the changing nature of the farming systems provide both opportunities and challenges. The challenges are particularly exacerbated in the global south, characterized by fragmented land ownership, rural population growth, and the increasing impact of climate change (Zhu and Guo, 2014; Pribadi and Pauleit, 2015; Chen *et al*., 2018; Follmann *et al*., 2021). To overcome the challenges and seize the opportunities that urbanization creates, actions and policies should support farming systems in the rural-urban continuum to absorb any imminent shocks and challenges, adapt to changes, and continue functioning to ensure food security at multiple scales.

Using resilience thinking, this study aims to understand if and what type of farming systems in the rural-urban continuum of Hyderabad, India can evolve and adapt to a changing environment, driven by urbanization and other pressures. This study is part of a joint project between the Swedish University of Agricultural Sciences (SLU) and ICRISAT on "The Dynamics of Urban Sprawl: Land-use Changes, Food Supply & Sustainable Agriculture Production Systems in the Arid and Semi-Arid Zones". The project is aimed at identifying the resilience and adaptive capacities of arid and semi-arid agroecological systems to urbanization. This article is built upon the farming system characterization done in the study area as part of the above-mentioned project.

Methods

LITERATURE REVIEW

A major consequence of urbanization is urban sprawl, which is the informal, fragmented expansion of cities into surrounding rural areas. This process is driven by a variety of factors such as urban planning failure, lower land prices, increasing population, migration, low cost of transport, and rising incomes (Cobbinah and Amoako, 2012; Brody, 2013; Youssef *et al*., 2020).

The result is the formation of peri-urban areas, transitional zones between rural and urban spaces characterized by poorly defined boundaries, land-use heterogeneity and interdependent rural-urban dynamics (Butt, 2013; Hedblom *et al*., 2017; Gioffrè, 2019; Vindigni *et al*., 2021). These hybrid spaces contain agricultural lands, residential settlements, and infrastructure such as expressways, railways and dams side by side, and the way land is used within them is constantly evolving. Rather than viewing peri-urban areas as temporary zones awaiting inevitable urbanization, a growing body of research recognizes their critical role in contemporary urban systems. These areas perform several important functions: they absorb urban expansion, house infrastructure, and sustain agricultural production close to consumption centers. Peri-urban agriculture has the potential to supply fresh food to cities, reduce transport-related emissions, preserves biodiversity, and maintain open spaces that contribute to urban resilience. Designing policies that maximize this potential, while limiting negative environmental and ecological impacts, is a key challenge for urban planning in the 21st century (Vindigni *et al*., 2021).

The effects of urbanization on peri-urban farming systems vary considerably across regions. In Europe, urbanization has emerged as a driving factor promoting multifunctional agriculture (Zasada, 2011; Meraner *et al*., 2018). In response to the demand from urban consumers in terms of post-harvest processing and recreational services, farmers in Europe have responded by intensification and diversification of farm activities (Zasada, 2011). Direct marketing of farm produce, shorter supply chains, on-farm specialization, on-farm diversification to include food processing, and non-productive recreational activities such as horse keeping, agro-tourism, and hobby farming have emerged as a response from farmers in peri-urban areas (Zasada, 2011; Meraner *et al*., 2018; Wästfelt and Zhang, 2018; Beckers *et al*., 2020).

In the Global South, urbanization presents a more complex picture of challenges and opportunities. Urban expansion threatens livestock and fisheries systems while contributing to water and soil quality degradation (Hussain and Hanisch, 2014; Youssef *et al*., 2020; Thapa *et al*., 2021). Wastewater-irrigated agriculture, increased farm wages, changing urban weather profile, increasing number of landless farmers, and high cost of farming are the effects of urban growth on urban and peri-urban agriculture (UPA) in the global south (Hussain and Hanisch, 2014; Kuusaana and Eledi, 2015; Padgham *et al*., 2015; Gumma *et al*., 2017; Follmann *et al*., 2021). Concurrently, better education and health infrastructure, higher wages, and employment opportunities act as pull factors for rural-urban migration (Abhishek *et al*., 2017; Mlambo, 2018). This also leads to reduction in the labor available for farming in rural areas, increased urban population, congestion in housing and traffic, urban unemployment, and increased crime rates (Mlambo, 2018). However, urbanization also creates market opportunities: rising urban population and income levels drive increased quantity and quality of food demand, prompting shifts from traditional staple crops toward higher-value produce such as fruits, vegetables, milk, eggs, and meat (IFPRI, 2017; Follmann *et al*., 2021).

In India, Industrialization, population size, education, and a political bias favoring the state capitals are some of the factors driving urban expansion (Abhishek *et al*., 2017; Varkey and Manasi, 2019). The urban population in India has steadily increased at a growth rate of 31.8%, which is higher than the average population growth rate of 17.64%. (Shekhar, 2021). Such accelerated urban expansion presents many ecosystem and social challenges (Gumma *et al*., 2017; Sultana and Satyanarayana, 2018; Wakode *et al*., 2018).

With urbanization affecting the key resources in a farming system, such as land, water, and labor, it is critical to appraise its role in the evolution of farming systems. A framework to appraise the farming systems from a social, agroecological, and economic perspective is facilitated by the concept of resilience. Resilience

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is the ability of a system to continue its functions, maintain its identity, and responses under stress while adapting to changing conditions (Carpenter *et al*., 2001; Folke *et al*., 2002; Walker *et al*., 2004). Recognizing the factors which enable a system to function in a hostile environment is at the core of the concept of resilience (Ifejika Speranza *et al*., 2014). It shifts the focus of policies from the changes in the system which are perceived as permanent to the capacities of the socio-ecological systems that enable them to cope and adapt (Berkes *et al*., 2003; Folke, 2006; Smit and Wandel, 2006). Emphasis on the resilience of farming systems is based on the recognition that it is essential to move away from the analytical concept of equilibrium (Scoones *et al*., 2007; Darnhofer *et al*., 2010). Resilience as a concept plays an important role in identifying and strengthening the characteristics of a farming system that can cope with shocks and stresses. To strengthen the capacities of resilience, we ought to measure them empirically (Carpenter *et al*., 2001). Several theoretical conceptualizations and methodological approaches exist for the assessment of resilience capacities (Carpenter *et al*., 2005; Cumming *et al*., 2005; Cabel and Oelofse, 2012; Ifejika Speranza *et al*., 2014; Jacobi *et al*., 2015; Jacobi *et al*., 2018; Meuwissen *et al*., 2019; Roy *et al*., 2019). The objective of this article is to measure the resilience capacities of different farming systems in the study area and to isolate the impacts of urbanization on them to the extent possible.

MATERIALS

Study area and data collection

Hyderabad, the capital city of the southern state of Telangana, is the sixth-largest metropolis in the country. It is located in the Musi sub-basin which is a part of the Krishna River basin. It consists of 12 municipalities, including the Greater Hyderabad Municipal Corporation. Rapid development, increasing job opportunities, and economic growth have attracted skilled and unskilled labor from across the country pushing the city's population to 10.3 million (WPR, 2021). From 2005 to 2016, the built-up area in Hyderabad constituting housing and other buildings has increased from 38,863 to 80,111 ha; unfavorably affecting the water bodies and rainfed cropland (Gumma *et al*., 2017). The land under agriculture within the city limits has decreased with the ongoing infrastructure development with seasonal waterbodies being abused the most for building purposes. This has resulted in a shift in land use, mainly from farmland to built-up areas. There is also a rise in wastewater-irrigated agriculture on the banks of the Musi River, which flows through the city, for vegetables and paddy cultivation to accommodate the rising urban demand (Gumma *et al*., 2011; Gumma *et al*., 2017). In Hyderabad, along with an increase in the area under wastewater-irrigated agriculture, there is a trend toward the cultivation of vegetables from the traditional crops of paddy, corn, and sorghum. With the increasing built-up area, the most significant land cover lost is of water bodies, which has resulted in an increased area under rainfed agriculture (Gumma *et al*., 2017).

Based on the findings of Gumma *et al*. (2017), field explorations were conducted. Structured interviews were conducted with local experts and officials of the Department of Agriculture to identify the study area (Fig. 1). The study employed interviews with local experts, government officials, and local progressive farmers to identify the issues faced by the local farming community and upcoming trends and opportunities due to the proximity of Hyderabad. Based on these interactions, six villages (Gundlapally, Guddamallaiguda, Mothakundur, Mulugu, Fareedpur, Kummera) were identified from blocks (Nalgonda, Ibrahimpattanam, Mothakundur, Mulugu, Haveli

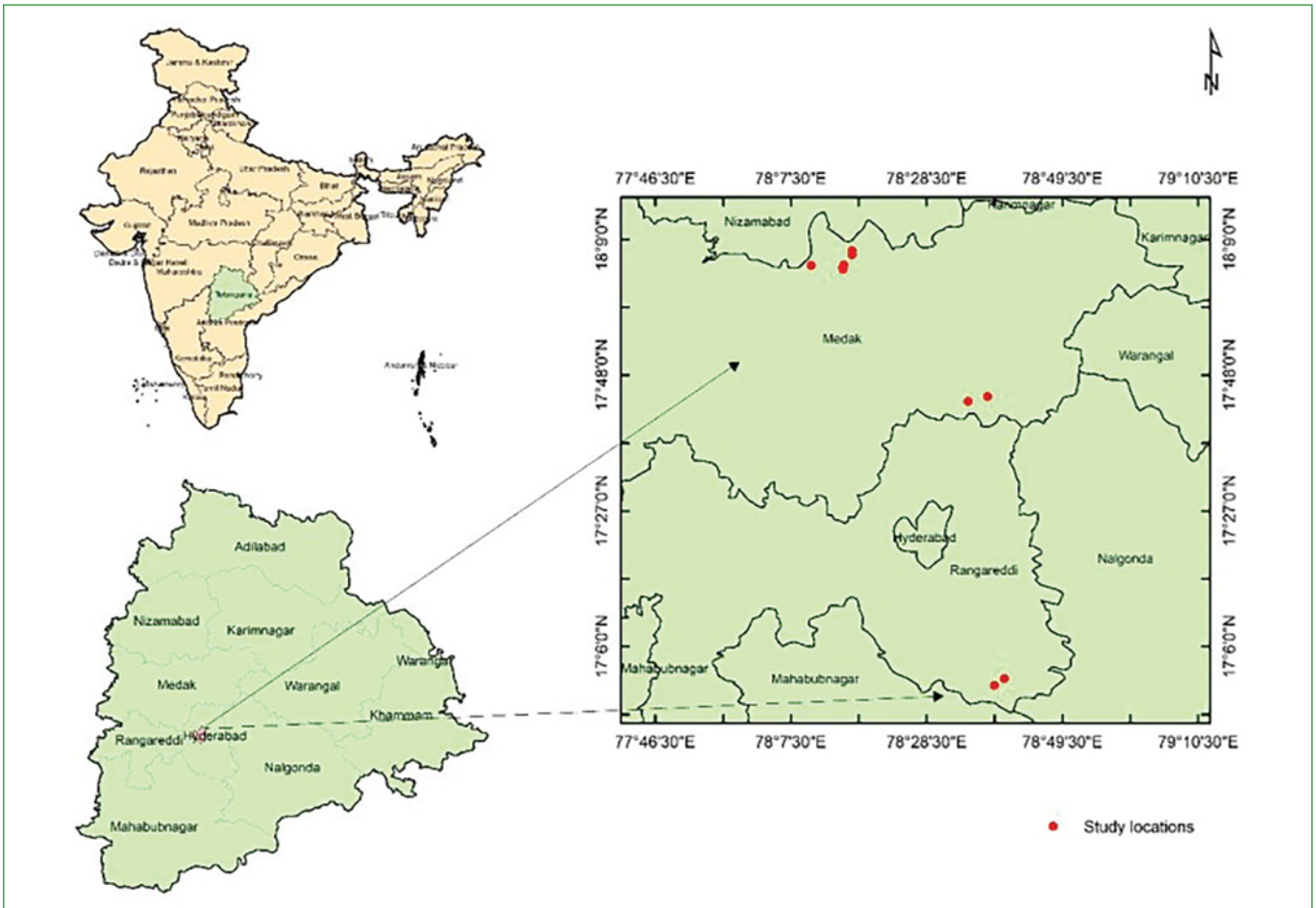


Fig. 1. Study area.

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Ghanpur, Chevella) around Hyderabad to conduct focus group discussions with farmers. Discussions were conducted in Telugu with the help of enumerators using a predesigned instrument. The discussions were recorded and further translated into English. The predesigned instrument focused on various aspects of a farming system, i.e., crop and livestock production, use of labor and machinery in agricultural practices, marketing channels employed, and the impact of urbanization observed by the farmers on the agricultural activities. In the next stage, blocks of Haveli Ghanpur, Mulugu, and Yacharam were selected for the farm household survey based on the understandings derived from the focus group discussions. The survey was conducted in August–September, 2021. A sample of 400 respondents was selected randomly from 10 villages within these blocks. The farm households were selected at random subject to the consent of an adult male and female household member to participate in an interview. The interviews were conducted in Telugu and responses were translated into English.

Conceptual framework

"The ability of a farming system to cope with challenges can be conceptualized as resilience" (Folke *et al*., 2010; Folke, 2016; Bullock *et al*., 2017; Meuwissen *et al*., 2019). According to Meuwissen *et al*. (2019), robustness, adaptability, and transformability are the three system capacities that are critical to understanding the resilience of farming systems. Meuwissen *et al*. (2019) explain robustness as "the capacity of a farming system to withstand stresses and (un)anticipated shocks"; Adaptability as "the capacity to change the composition of inputs, production, marketing and risk management in response to shocks and stresses but without changing the structures and feedback mechanism of the farming system"; and Transformability as "the capacity to significantly change the internal structure and feedback mechanism of the farming system in response to either severe shocks or enduring stress that makes business as usual impossible". Resilience is a holistic concept that is difficult to measure in its entirety due to its nature and (Carpenter *et al*., 2005; Cumming *et al*., 2005; Darnhofer *et al*., 2010; Cabel and Oelfose, 2012). Thus, it is suggested that a set of indicators to assess resilience is a more useful approach than trying to measure resilience itself (Carpenter *et al*., 2001; Bennet *et al*. 2005; Darnhofer *et al*., 2010a; Cabel and Oelfose, 2012). Its segmenting into capacities makes it feasible to identify indicators that depict them (Jacobi *et al*., 2015). Carpenter *et al*., (2001) highlights that the attributes of a system that grant resilience depend on its context making the indicators of resilience context-dependent. Against this backdrop, we identified the following indicators for the assessment of the resilience capacities of the farming systems in the study area.

It is important to note that farming systems are highly complex and variable in time and space (Darnhofer *et al*., 2012) making it very difficult to identify aspects that contribute to their resilience (Cumming *et al*., 2005). Darnhofer *et al*. (2010a) list the challenges associated with the task of identifying indicators of resilience. First is a temporal challenge i.e., the indicators may change as the farming system evolves. The second is the spatial hurdle i.e., the indicators are specific to location and the third is the human dimension i.e., the farmers' perceptions and intentions about their farms. The relation between these indicators and resilience is dynamic and multidimensional in nature. There are trade-offs across resilience attributes i.e., an attribute that confers robustness to the system may be doing so at the cost of adaptability. At the same time, as the farming system evolves, an attribute that enhances the resilience today may affect the resilience of the farming system negatively with the change in domain.

Indicators for each resilience capacity were identified through a systematic process combining literature review, field validation, and expert consultation. We began with indicators commonly used in resilience assessments of farming systems, drawing particularly from the Resilience Index Measurement and Analysis (RIMA) methodology (FAO) and frameworks developed by Jacobi *et al*. (2018) and TANGO International (2018). These were then validated during FGDs with farmers to assess their relevance to the local context and the specific pressures of urbanization in the study area. Final selection was made in consultation with local agricultural scientists based on four criteria: relevance to the urbanization context, measurability, data availability, and feasibility of collection within the household survey.

The selected indicators reflect the specific dynamics of peri-urban farming systems. Indicators such as distance to city, distance to market, and access to infrastructure capture the urbanization gradient and its indirect effects (Tables 1–3). Cultivation of high-value crops and market access reflect farmer responses to urban demand. Livelihood diversification captures the pull of urban labor markets. Access to land and irrigation – key constraints identified in the focus group discussions – address the direct effects of urbanization on natural resources. Buffer capacity indicators such as agricultural income, assets, livestock, and access to safety nets capture the ability of households to absorb shocks. Finally, indicators related to information access, social networks, and agricultural services capture the enabling conditions for adaptation and transformation.

METHODOLOGY

We use principal factor analysis to combine these indicators of resilience into indexes (TANGO International, 2018). Factor analysis is a multivariate statistical method that uses the relationship among variables to identify one or more underlying factors. A "factor" is an unobservable or latent variable that can be understood through its relationship with other variables that can be observed and measured. Resilience measurement is not possible using a single variable as the concept is multifaceted. Thus, a scale is developed based on various indicators that capture various aspects associated with resilience capacity. Factor analysis allows the researcher to calculate the relative weights of the respective index components based on these inter-correlations and create a single variable i.e., the index. Data analysis was conducted using STATA 14. Further, orthogonal rotation was used.

We applied factor analysis to calculate index weights which are further used in the calculation of the resilience capacity index. A Kaiser-Meyer-Olkin (KMO) test is used to confirm that the index components have enough in common to warrant factor analysis. In the next step, the index is calculated for the resilience capacities using the weights derived from factor analysis. For reporting purposes, the index is standardized and placed on a scale of 0–100 using minimum and maximum values. Further, average values of each resilience capacity for each of the farming systems are calculated to help understand the contribution of each capacity and for comparison of resilience capacities across farming systems.

The current study aims to contribute to the growing literature on understanding the effects of urbanization on the resilience of farming systems in the context of rapidly developing cities (Table 4).

1. Monocropping without livestock (FS1)
2. Diverse cropping without livestock (FS2)
3. Monocropping with dairy (FS3)
4. Diverse cropping with dairy (FS4)
5. Cropping with small ruminants (FS5)

Results

The results of the factor analysis are presented in Table 5.

FACTOR ANALYSIS

Please refer to Table 5: Results of the factor analysis.

Robustness

Based on the results of the factor analysis, agriculture income, direct benefit transfers from government schemes, access to irrigation, access to farmland, and food crop production contribute positively

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Table 1. Indicator components in the Robustness index.

Robustness indicators	Description/interpretation	References
Agricultural income	A total of crop income, livestock income, and farm wages. Agricultural income allows farmers to build wealth thus building buffer capacity and making the system robust.	Cabel and Oelofse (2012), Ifejika Speranza *et al*. (2014), and Jacobi *et al*. (2018)
Access to safety net	If the farm household participates in MGNREGS.[1] Access to safety nets makes the farm household robust to shocks and stresses	TANGO International (2018)
Direct benefit transfers	Total benefits from Pradhan Mantri Kisan Samman Nidhi[2] and Rythu Bandhu Scheme[3] Benefits from the government schemes add to the buffer capacity and allow farmers to invest in the future	
Access to irrigation	Gross irrigated area in acres Access to irrigation allows the farmer to undertake cultivation across seasons making the system robust to seasonal socks/ stresses	Jacobi *et al*. (2018)
Gross cropped area	Gross cropped area in acre Farmland accessible across seasons makes the farming system robust to seasonal shocks/stresses	Jacobi *et al*. (2018)
Food production	Gross area under food crops in acres (excluding area under HVC) Supply of fresh food is a key function of the farming system which contributes to the food security of the farm household making it robust to the price shocks.	Jacobi *et al*. (2018)
Assets	The total of assets owned by the household These assets indicate the wealth of the farm HH which can be tapped into in times of shocks/stresses.	Ifejika Speranza (2013), Ifejika Speranza *et al*. (2014), Jacobi *et al*. (2018), and TANGO International (2018)
Livestock	Tropical Livestock units Livestock serves as a cushion against economic shocks such as crop failure.	Ifejika Speranza (2013) and Jacobi *et al*. (2018)
Dependency payments	Total benefits from various pension schemes and remittances Access to dependency benefits reduces the financial burden of dependents in the household thus freeing up resources for farming	TANGO International (2018)
Access to network	If any member of the household is a member of any organization Social networks serve as an insurance mechanism in times of economic stress/shocks,	Cabel and Oelofse (2012), Ifejika Speranza (2013), Ifejika Speranza *et al*. (2014), and Jacobi *et al*. (2018)
Use of organic inputs	If the household is using manure as a farm input The use of resources available locally reduces market dependence making the system robust	Cabel and Oelofse (2012)

[1]MGNREGS (Mahatma Gandhi National Rural Employment Guarantee Scheme, provides a legal guarantee of 100 days of employment to adults of rural households willing to do unskilled manual work at statutory minimum wage.
[2]Pradhan Mantri Kisan Samman Nidhi (Pradhan Mantri Kisan Samman Nidhi is an initiative by the government of India that gives farmers up to ₹6000 per year as minimum income support.)
[3]Rythu Bandhu Scheme (Rythu Bandhu Yojna, also known as Farmer's Investment Support Scheme is a welfare program to support farmer's investment for two crops per year by the state government of Telangana.)

to the robustness of the farming system. While household assets, and livestock (TLU) have no significant impact on the robustness of a farming system, access to safety nets such as MGNREGA and pension benefits affect it negatively. This is explained by the practice of informally leasing out farmland, thus suspending farming activities.

Adaptability

Crop diversity and area under high value crops influence the adaptability of the farming systems positively. Livestock (TLU), assets, and the use of organic inputs do not have a significant influence on the adaptability of the farming systems in the study area. Non-farm activities are preferred as the reliable and regular source of livelihood over the uncertainties linked with farm income. Thus, non-farm diversification has a negative impact on the adaptability of the farming systems.

Transformability

Access to agricultural inputs and services and supporting infrastructure contributes positively to the transformability of the farming systems. Distance to the city has a negative influence on the transformability of a farming system indicating an inverse relationship between the distance to the urban center and the transformability of the farming systems in the study area. Access to network, access to information, and access to safety nets do not significantly impact the transformability of the farming systems. Notably, women's participation in the decision-making process regarding household activities and control over income does not contribute significantly to transformability. This may indicate that gender diversity in terms of decision making in itself does not add to transformability without the support of complementary infrastructure and services.

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Table 2. Indicator components in the Adaptability Index.

Adaptability indicators	Description/interpretation	References
Crop diversity	Simpson's Crop Diversity Index Crop diversity indicates the change in crop choices in line with the changing market conditions of the farm household	Cabel and Oelofse (2012), Jacobi *et al*. (2018), and Roy *et al*. (2019)
Market access	No of the markets accessed by the household to sell its agricultural output. A variety of markets accessible to the farm household allows the farmer to diversify its product basket making it adaptable to changing market demand.	TANGO International (2018) and Roy *et al*. (2019)
Assets	A total of assets owned by the household. Assets indicate the wealth of the farm household, which allows it the flexibility to maneuver its activities	Ifejika Speranza (2013), Ifejika Speranza *et al*. (2014), Jacobi *et al*. (2018), and TANGO International (2018)
Livestock	Tropical livestock units Livestock rearing indicates a change in farmer strategies in line with the market demand	Ifejika Speranza (2013) and Jacobi *et al*. (2018)
Access to information	Access to information regarding market price, climatic conditions, agricultural technology adaptation, and agricultural practices through various sources Access to knowledge adds to the adaptive capacity of the farming system.	Cabel and Oelofse (2012) and TANGO International (2018)
Access to network	If any member of the household is a member of any organization Access to network facilitates the sharing of knowledge and past experiences thus adding to the adaptive capacity	Cabel and Oelofse (2012), Ifejika Speranza (2013), Ifejika Speranza *et al*. (2014), and Jacobi *et al*. (2018)
Distance to market	Distance to the nearest market in km Proximity to the market affects crop choices and production decisions in favor of the changing market conditions.	
Livelihood diversification	If the household has diversified into non-farm livelihood activities such as business/non-farm salaries employment/wages Non-farm income sources allow the farm household to invest in new technology and practices thus making it adaptable.	Cabel and Oelofse (2012) and Ifejika Speranza (2013), and TANGO International (2018)
Cultivation of high-value crops	The gross area under high-value crops in acres High-value crop cultivation indicates farm household adaptability to urban market demand.	Focus group discussions
Use of organic inputs	If the household is using manure as a farm input The use of manure indicates the preference for organic inputs for soil fertility and a shift away from inorganic inputs	Cabel and Oelofse (2012); Focus group discussion
Experience in farming	Years of experience in the farming of the head of the household indicating indigenous knowledge Experience of shocks/stresses/challenges and indigenous knowledge make the system more adaptable	Cabel and Oelofse (2012), Ifejika Speranza *et al*. (2014), and Jacobi *et al*. (2018)

Table 3. Indicator components in the Transformability index.

Adaptability indicators	Description/Interpretation	References
Access to network	If any member of the household is a member of any organization. Access to the network provides the support and knowledge needed for transformation.	Cabel and Oelofse (2012), Ifejika Speranza (2013), Ifejika Speranza *et al*. (2014), and Jacobi *et al*. (2018)
Access to safety net	If the farm household participates in MGNREGS. Access to the safety net acts as an insurance mechanism to risks involved in transformation.	TANGO International (2018)
Access to agricultural services	Access to agricultural services such as storage facilities, agricultural inputs, veterinary services, and hired labor Access to knowledge and infrastructure adds to the capacity of transformability.	Jacobi *et al*. (2018) and TANGO International (2018)
Access to information	Access to information regarding market price, climatic conditions, agricultural technology adaptation, and agricultural practices through various sources Access to knowledge adds to the transformability capacity of the farming system	Jacobi *et al*. (2018) and TANGO International (2018)
Access to supporting infrastructure	Access to health, education, and transportation facilities Access to infrastructure facilitates transformability and contributes to human capital building, which, in turn, further adds to transformability.	Cabel and Oelofse (2012) and TANGO International (2018)
Gender diverse decision making	Participation of both genders in the decision making Women's participation in the decision making process adds to transformability	TANGO International (2018)
Distance to city	Distance to Hyderabad in km Proximity to the city is an indicator of access to markets, infrastructure, and services which add to the transformability.	

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Table 4. Farming systems in the study area.

		FS1	FS2	FS3	FS4	FS5
Sr. no	**Characteristic**	**N = 217 54.25%**	**n = 76 19%**	**n = 33 8.25%**	**n = 26 6.5%**	**n = 14 3.5%**
1.	Farm size					
	Marginal	133 (61.29%)	43 (56.57%)	20 (60.60%)	6 (23.07%)	7 (50%)
	Small	50 (23.04%)	23 (30.26%)	4 (12.12%)	11 (42.30%)	4 (28.57%)
	Semi-medium	23 (10.59%)	7 (9.21%)	6 (18.18%)	6 (23.07%)	2 (14.28%)
	Medium	10 (4.60%)	3 (3.94%)	3 (9.09%)	2 (7.69%)	1 (7.14%)
	Large	1 (0.46%)	0	0	1 (3.84%)	0
2.	Crops	Paddy, cotton	Paddy, maize, cotton, redgram, vegetables	Paddy, cotton, fodder	Paddy, maize, cotton, redgram, vegetables	Paddy, cotton
3.	Irrigation characteristics	Irrigated, rained	Irrigated, drip irrigation	Irrigated, rainfed	Irrigated, drip irrigation	Irrigated, rainfed
4.	Livestock characteristics	–	–	Local cattle, exotic/ cross breed cattle	Local cattle, exotic/ cross breed cattle	Small ruminants
5.	Farm operations: Mechanized	Land preparation, harvesting	Land preparation, harvesting	Land preparation, harvesting	Land preparation, harvesting	Land preparation
6.	Locations	Yacharam, Mulugu, Haveli Ghanpur	Yacharam, Mulugu	Yacharam, Mulugu, Haveli Ghanpur	Yacharam, Mulugu	Yacharam, Mulugu, Haveli Ghanpur

[Farm size: Marginal = < 1 ha, Small = 1–2 ha, Semi-medium = 2–4 ha, Medium = 4–10 ha, Large = 10 ha <]
(Agriculture census by Government of India, 2015–2016).
(Note: 34 HH were excluded from farming systems categorization. While 29 HH had leased out their farmland, 5 HH could not be categorized due to the nature of their farm activities.)

Table 5. Results of the factor analysis.

Robustness			**Adaptability**			**Transformability**		
Indicator	**Unrotated**	**Rotated**	**Indicator**	**Unrotated**	**Rotated**	**Indicator**	**Unrotated**	**Rotated**
Agricultural income	0.8229	**0.7883**	Crop diversity	**0.6811**	**0.7213**	Access to network	−0.2665	−0.1668
Access to safety net	−0.0636	−0.0379	Market access	**0.5899**	0.2681	Access to safety net	−0.3220	−0.2324
Direct benefit transfers	**0.7550**	**0.7131**	Assets	0.2200	0.0478	Access to agricultural services	**0.5246**	**0.5780**
Access to irrigation	**0.9621**	**0.9697**	Access to information	0.3414	0.2228	Access to supporting infrastructure	**0.7029**	**0.7068**
Access to farmland	**0.9629**	**0.9727**	Access to network	−0.0768	−0.1981	Access to information	0.3294	0.2445
Food production	**0.9535**	**0.9716**	Distance to market	−0.2736	−0.1161	Distance to city	**−0.514**	−0.4277
Assets	0.3638	0.3216	Off-farm diversification	−0.1745	−0.1681	Gender diversity	−0.1604	−0.0566
Dependency benefits	−0.0694	−0.0614	Area under HVC	0.6271	0.7325			
Access to network	−0.0039	0.0028	Use of organic inputs	0.4991	0.2505			
Use of organic inputs	0.0199	−0.0008	Years of experience in farming	−0.0023	−0.0659			
No of livestock	0.0828	0.0681	No of livestock	0.2649	0.0479			

[For Robustness, KMO value = 0.7271; For Adaptability, KMO value = 0.6406; For Transformability, KMO value = 0.7604]. Factor loadings higher than 0.5 have been highlighted in bold.

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RESILIENCE CAPACITIES OF THE FARMING SYSTEMS

(Please refer to Table 6: Resilience capacities index scores)

There is an inherent trade-off in the capacities of the resilience of a farming system (Darnhofer *et al*., 2010a). What may add positively to the robustness of a farming system, may contribute negatively to its adaptability. We observe such trade-offs in our study. FS4 has the highest robustness while FS2 scores highest in terms of the adaptability and transformability. These results highlight the importance of context of the study, the trade-off among resilience capacities, and the dynamic nature of resilience as a property of a system.

The farming system FS2 consists of farm households that practice diverse high value cropping without any livestock rearing activities. The majority of the households own small and marginal farms (87%). These farm households are located in the peri-urban region of the study area. Thus, with crop diversity and access to market, this farming system ranks high in terms of adaptability. With access to infrastructure and services, proximity to the city, this farming system ranks high in terms of transformability. However, with lower access to farmland (which also limits access to direct benefit transfers linked to land ownership), this farming system ranks lowest in terms of robustness.

On the other hand, farming system FS4 consists of farm households practicing diverse cropping and dairy activities. While 65% of households are small and medium farms, 30% of households are semi-medium and medium farms. These households are located in the peri-urban region of the study area. With the supplementary agricultural income from dairy activities, better access to farmland and direct benefit transfers, this farming system ranks highest in terms of robustness. However, it also ranks second highest in terms of adaptability and transformability as well facilitated by crop diversity, market access, access to infrastructure and services, and proximity to the city.

Discussion

The spatial distribution of farming practices reflects the market effects of urbanization. Diverse cropping households are concentrated in the peri-urban region, with the majority cultivating vegetables for urban markets. This pattern of intensification and diversification in peri-urban areas is consistent with findings from other rapidly urbanizing contexts (Hussain and Hanisch, 2014; Meraner *et al*., 2018; Wästfelt and Zhang, 2018; Follmann *et al*., 2021) and confirms that proximity to urban markets drives shifts toward higher-value production systems.

Social protection programs play a complex role in shaping household strategies. Land owning farmers receive cash transfers from two direct benefit schemes i.e., the Rythu Bandhu Yojana implemented the State Government of Telangana and the Pradhan Mantri Kisan Samman Nidhi implemented by the Government of India. These schemes are aimed at supporting the farmers in the face of rising input costs. While they contribute significantly to the robustness of farming systems, we observe that many farm households, particularly elderly farmers, rely on these benefits as a steady source of income. Additionally, all the households in the study area have access to social safety net schemes through the MGNREGA. However, instead of accessing it in times of economic shocks, it is perceived as a reliable source of paid work. Our findings suggest that rather than serving solely as a safety net during economic shocks, these programs may have become integrated into regular household income strategies. We observe that some farm households, particularly those with elderly members, lease out farmland informally while retaining land ownership to continue receiving land-linked benefits. This pattern suggests a modification of livelihood portfolios in response to improved income security. These observations indicate that direct benefit transfers and access to safety nets may be indirectly contributing to the transformability of farm households by facilitating gradual exits from active farming.

Table 6. Resilience capacities index scores.

	FS1	FS2	FS3	FS4	FS5
Robustness					
Mean	28.232	25.556	32.373	**40.717**	30.296
S.D.	27.348	17.824	26.655	24.285	20.398
Adaptability					
Mean	12.743	**67.393**	10.405	66.731	19.170
S.D.	7.140	13.538	3.600	24.060	11.336
Transformability					
Mean	52.151	**70.263**	49.397	66.617	54.792
S.D.	22.445	13.538	22.594	15.539	**14.781**

Average index score for farming system which performs highest for each resilience capacity is highlighted in bold.

This study has several limitations that should be acknowledged. First, the cross-sectional design captures resilience capacities at a single point in time, whereas resilience is inherently dynamic. The resilience indicators identified may change as farming systems evolve in response to continued urbanization. Second, the findings are context-specific to the peri-urban areas of Hyderabad and may not be generalized to other Indian cities or regions with different urbanization trajectories. Third, indicator selection was constrained by data availability and feasibility of collection; potentially important factors such as soil quality, tenure security among others were not captured.

Conceptually, this study draws on the framework developed by Meuwissen *et al*. (2019) but focuses only on a set of resilience capacities rather than the full set of resilience attributes such as system reserves, tightness of feedback, and openness. Additionally, the study assesses overall resilience rather than resilience with respect to specific functions. Farming systems perform multiple private functions (providing affordable food, supplying raw materials, generating livelihoods) and public functions (maintaining natural resources, protecting biodiversity, preserving rural social structures). Assessing the resilience of these specific functions under urbanization pressure remains an important direction for future research. Longitudinal studies tracking the same farming systems over time would also strengthen understanding of how resilience capacities evolve as urbanization proceeds.

CONCLUSIONS

Urbanization has a mixed impact on the resilience of the farming systems. The indirect effects of urbanization, i.e., *market effect and the technical efficiency effect* contribute positively to the adaptability and transformability of the farming systems by facilitating market access, demand for high-value crops, access to infrastructure, and agricultural services. It *directly* affects the robustness of the farming systems negatively by constraining access to natural resources, i.e., land and water. It also negatively affects the adaptability of farming systems by facilitating access to off-farm employment, which is facilitating farm exits. Of the farming systems studied, FS4 has the highest robustness while FS2 scores highest in terms of adaptability and transformability. Hence, farm strategies and policies that support diversification of on-farm activities and high-value crop cultivation should be promoted. Policy instruments should be designed to ensure access to farmland and irrigation in line with urban expansion. However, urbanization is a dynamic process. Its impact on farming systems, which are dynamic in their own right, will lead to a complex set of interactions having multifaceted effects. As urban expansion continues, it will change the attributes or the nature of attributes that contribute to the resilience of these farming systems.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ETHICS STATEMENT

The authors confirm that the research meets any required ethical guidelines, including adherence to the legal requirements of the study country.

AUTHOR CONTRIBUTIONS

KG contributed in conceptualization, literature review, methodology, data collection, formal analysis, writing-original draft, editing; *NS contributed in* conceptualization, writing-review, supervision; and *DK contributed in* conceptualization, writing-review, supervision.

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DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

INSTITUTIONAL REVIEW BOARD STATEMENT

The study has received ethical approval from the Institutional Ethics Committee (IEC) of the International Crop Research Institute for the Semi-Arid Tropics. The IEC Clearance Number is IEC-ICRISAT/20201126/07.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

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