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Managing food at urban level through water–energy–food nexus in India: A way towards holistic sustainable development

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Abstract
With rise in population growth and increasing trend towards urbanization, urban spaces have become 'hot spots' for intensive resource use including water, energy and food (WEF). Thus, along with food production, food management from consumption side is equally important to address the issue of WEF resource scarcity. An analysis of urban food management in India was carried out through systematic study of different government documents. In-depth content analysis across five sectors, namely water, energy, food, urban and environment, was carried out to find parameters for urban food management strategies having linkage with WEF resources. The study identified six parameters under two categories, namely city region food systems (urban/peri-urban agriculture, green roof technology, urban farmers market) and managing food wastes (reducing food wastes, compost from waste, energy from wastes). The analysis revealed that urban food management in India is focused on managing food wastes through solid waste management strategies (compost and energy production). City region food system and role it plays in optimizing WEF nexus need the attention of policy makers. The study concludes that a paradigm shift is required towards integrated urban WEF policy to attain the goals of sustainable urban development in the developing nations of Global South.

Keywords Food policy · Global South · Sustainable development · Urban region · Water–energy–food nexus

1 Introduction

India made a significant progress in agricultural production, increasing its food grain production capacity from 108 million tons in 1970's to 284.83 million tonnes in 2017–2018 (Ministry of Agriculture and Farmer's Welfare Report, 2018a). The comparative analysis of last five years also shows an increase in 10% of food grain production from 2013 to

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2014, highlighting various policy initiatives taken by the government to enhance agricultural production. With 2.4% of total land area (Bhattacharya et al., 2015), India ranks competitive position in the world in the production of major cereals and crops. According to the Agricultural Statistics Report of 2018, India ranks first in pulses production and second in terms of paddy, wheat and sugarcane production. Per capita availability of food grains in India has also grown from 144.1 kg/year in 1951 to 180 kg/year in 2018 (Ministry of Agriculture and Farmer's Welfare Report, 2018b), showing a significant increase of 25% in the consumption pattern. Per capita availability of rice and wheat has increased from 58 kg/year to 69 kg/year and 24 kg/year to 64.4 kg/year from 1951 to 2018, respectively. The credit for such progress goes to "First Green Revolution (FGR)" that started in late sixties and made India from a country of food grain importer to food grain exporter (Ahmad & Haseen, 2012; Swaminathan & Bhavani, 2013; Pingali et al., 2019).

Though the FGR averted the hunger of millions of people, but it has been criticized by ecologists for its detrimental consequences on the land and water resources of the country, which had led to the loss of biodiversity and caused socio-economic disparities (Swaminathan, 2003). The use of high yielding varieties of seeds demanded heavy application of chemical fertilizers and extensive irrigation (Nelson et al., 2019). The negative impacts were further aggravated by the policies that were used to promote rapid intensification of agricultural systems to increase food supplies (Pingali et al, 2019). Review of agriculture policies in India highlights the lack of framework for efficient and sustainable water use, low or absent water-charging for surface water used in irrigation and energy subsidies for groundwater pumping have been driving severe depletion of resources (Barik et al., 2017; Dey, 2009; Jha & Sinha, 2007; OECD, 2018). Electricity consumption in agriculture witnessed a sharp increase of 74% between 1983–84 and 1995–96. This was the time of rapid expansion in tube-well irrigation in the Indo-Gangetic plain (Jha et al, 2012). Irrigation is the largest consumer of world's fresh water. According to the report of United Nations World Water Assessment Program, agriculture accounts for 70% of global water withdrawals in the world (WWAP, 2018). Water and energy consumption of major food grain producing states of India is shown in Fig. 1. The stage of ground water development in Punjab, Rajasthan and Haryana states is more than 100 percent, which implies that groundwater consumption is more than annual ground water recharge (Fig. 1).

Imbalanced use of chemical fertilizers and over-exploitation of groundwater in North-Western States of India had led to the genesis of second wave of green revolution in the resource-rich eastern part of the country (Bhatt et al., 2016; MoAFW, 2018a). The concept of "Ever-Green Revolution" was given by M.S. Swaminathan that stressed on increasing the crop productivity by adopting the technologies based on "integrated resource management" (Swaminathan, 2003). The knowledge of genetic engineering and information technology has been driving the second green revolution (SGR) among scientific community (Davies, 2003; Dey, 2009; Pingali, 2019). In spite of all these progresses, there is immense pressure on Indian agriculture to produce more and efficiently to feed the growing and urbanizing population amidst the challenges like water scarcity, energy insecurity and limited land.

1.1 Understanding urbanizing trends in India

India is predominantly an agriculture country as approximately 55% of total workforce is engaged in agricultural and allied activities (MoAFW Report, 2018a). But in terms of overall gross development product (GDP) contribution, agriculture comes third after services

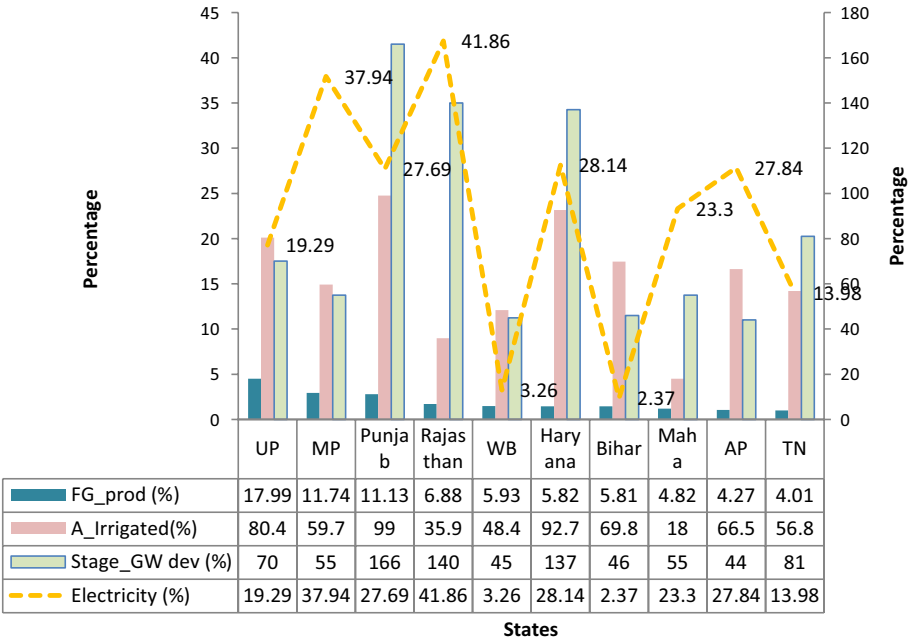

Fig. 1 Water and energy consumption of major food producing states of India. *Source*: FG_Prod (Food grain production), A_Irrigated (Area irrigated) and electricity- MoAFW Report, 2018b; Stage_GW dev (Stage of Ground water development)-CGWB Report, 2019).Note: UP = Uttar Pradesh, MP = Madhya Pradesh, WB = West Bengal, Maha = Maharashtra, AP = Andhra Pradesh, TN = Tamil Nadu

and industries and accounts for 17.1% of gross value added (GVA) for the year 2017–2018. In spite of promising government policies and schemes for agriculture production, the sector has shown a decrease of 18% from 2004–2005 to 2018–2019. During the same period, contribution of service sectors has expanded to 12% in last 15 years. India's economic growth has been characterized as service-led growth, and the gap is widening between agriculture and non-agricultural sectors (ILO, 2018). Increasing urbanization and demand for better services in urban areas is one of the reasons for such shift. Urban population of India grew to 377 million with 2.67 percent growth per annum during 2001–2011 (Census of India, 2011). The level of urbanization also increased from 27.78 percent in 2001 to 31.16 percent in 2011. A comparison of data for last 50 years indicates that the number of urban agglomeration, towns and cities has grown over three times. Thus, urban landscape of the country is witnessing increase in population, increase in number of cities as well as expansion of existing municipal boundaries.

With growing urban population, demand in every key service in cities and towns is also growing including demand in food supplies (Diehl, et al., 2019). According to FAO report 2018, approximately one-third of food produced gets lost across the food supply chain and consumption level. This food loss and waste accounts for 20% of freshwater and 38% of energy consumption (FAO, 2018). As per the Food Sustainability Index (FSI) which is based on three broad categories, namely, food loss and waste, sustainable agriculture and nutritional challenges, India has been poorly positioned at 33rd place among 67 countries (Murray, 2018).

With the increase in urbanization and living style of people, there has been change in dietary demand (ADB, 2013) and thus increase in water intensive food products like processed meat and dairy products. Agriculture faces an enormous challenge of producing almost 50% more food by 2030 and doubling its production by 2050 (Mohtar & Daher, 2012). However, potential of increase in world food production is limited due to the effects of resource-, market- and policy-related factors. Some major means of increasing world food supplies include increasing yields through improved technologies; more intensive use of currently cultivated land; by bringing uncultivated land into production; and by saving a greater proportion of crops that are produced (Heady et al., 2007) through food management strategies.

The cities in Global North have taken several policy related steps towards urban food management strategies. But such holistic approach and effort are missing in the growing cities of Global South (Schulterbrandt Gragg et al., 2018). One of the major challenges of existing policy efforts has been limited understanding of the holistic resource considerations and interconnections within the food system. Food management is not given due importance in urban planning and policy making in comparison with water and energy. In India, urban agriculture does not find any place in policy intervention. With rise in population growth and increasing trend towards urbanization, urban spaces have become 'hot spots' for intensive resources use including water, energy and food (WEF). Thus, along with food production, food management from consumption side is equally important to address the resource scarcity and narrow the socio-economic in equalities. It is apparent that traditional approach for managing WEF resources is no longer an option. Effective management is essential to achieve larger developmental objectives.

Urban WEF nexus has been defined by the scientific community as a complex but interrelated system where water, energy, food and waste treatment systems intersect (GIZ, 2015; Gold & Bass, 2010; Lehmann, 2018; Schulterbrandt Gragg et al., 2018) and outlines an approach for sustainable urban development. WEF nexus approach is viewed by many researchers as a conceptual framework for holistic implementation of SDGs (Biggs et al., 2015; Terrapon-Pfaff et al, 2018). Nexus discussion mainly revolves at global or regional level; local level challenges are not highlighted (Terrapon-Pfaff et al, 2018). For holistic approach towards WEF resources optimization, it is pertinent to link the goals of sustainable development. Multi-sectoral approach for WEF resources management is required to address the current challenges. Multidimensional problem requires policy intervention across range of different areas. WEF resources are interlinked due to dynamic and complex interaction; thus, vulnerability in one would affect the other resources as well. WEF resources are deeply interconnected and enables the structured analysis of policy integration across different scales (Marker et al., 2018), and to achieve the goals of sustainable development, it is important to focus on interdisciplinary approach (Aguilar-Rivera et al., 2019; WWAP, 2018).

Though WEF nexus is an emerging topic and is making a place in planning agendas, a systematic examination of policy development and its implementation from the food perspective at urban level is lacking in Indian context. Identifying the research gaps, we argue that less attention has been paid related to research on urban food governance dealing with strategic development and WEF nexus. There is lack of comprehensive framework to analyse urban food policy due to siloed and multi-stakeholder involvement. Thus, the aim of the present analysis is therefore (i) to understand urban food management strategies and its linkages with WEF nexus, (ii) gap analysis of current policy framework of India to manage urban WEF nexus from food perspective and (iii) to propose recommendations with reference to sustainable development goals.

2 Methodology

An explorative research approach has been applied in the analysis of urban food management situation in India. In the context of this study, we define an integrated food management strategy as a policy approach (Doernberg et al., 2019) which connects the issues of food in urban area with other policies related to water and energy at national level (Lehmann, 2018). A detailed methodological framework was developed for the purpose of the study which consists of six steps as shown in Fig. 2.

As elaborated in Fig. 2, the first step was identification of parameters related to urban food management in relation to WEF nexus. Different parameters were identified through extensive literature reviews. The parameters identified were based on two criteria (i) city region food management and (ii) managing food wastes at urban level. WEF resources that have an impact on urban food management based on the above two criteria were mapped using qualitative mapping technique (Armanda et al., 2019; Doernberg et al., 2019). To identify parameters, we used inductive thematic analysis (Adebiyi et al., 2020). The parameters were categorized and condensed based around the nexus elements. Different search terms and combination, namely water, energy, food, environment, climate, urban and peri-urban agriculture, food wastes, energy from wastes, compost from wastes, vegetables and food supply chain, urban farming and markets, were used to identify linkages between WEF resources and food management strategies at urban level.

After identification of parameters related to WEF nexus and urban food management, different institutions were identified with respect to WEF resources at national level and

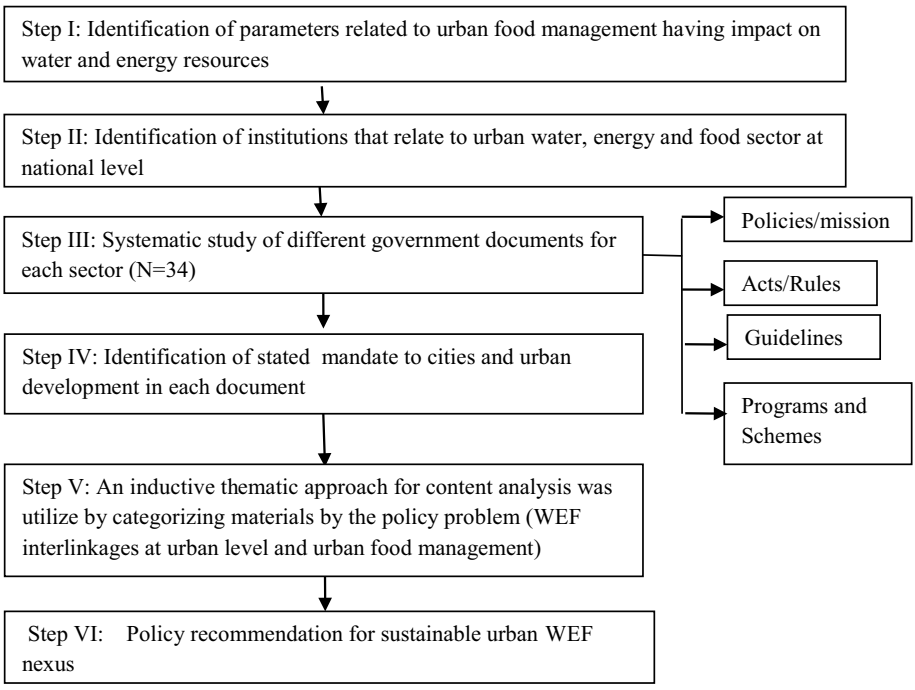

Fig. 2 Methodological framework designed for the study

their mandates were scrutinized. Based on their roles and responsibilities in the context of WEF resources and linkages with urban regions, institutions were selected for further document screening, analysis and systematic study.

Different policies, programmes or schemes of government that provide services at urban level within the context of WEF nexus were identified through desk research. Systematic review of programs and policies through content analysis was performed to ascertain relevant policy documents (Osslon, 2018). Stated mandates to cities and urban development in each document were screened thoroughly. The documents analysed were divided into four categories namely, (i) policies or mission documents, (ii) acts or rules, (iii) guidelines and (iv) programs and schemes. We only considered official documents that were available on the government websites for the time period of 2005–2019 which contained statements for the in-depth content analysis of the documents. For the purpose of the study, total 34 different documents were screened and analysed to find parameters identified for urban food management strategies. The identified parameters were further linked with different Sustainable Development Goals. The list of the intuitions screened and details of documents analysed has been given in supplementary material as "Appendix A".

3 Result

This section has been organized into two parts: (i) urban food management strategies and linkages with WEF nexus and (ii) present policy framework and gap analysis for WEF nexus management in India.

3.1 Urban food system management strategies and water–energy–food (WEF) nexus linkages

Food systems in developed countries are gaining due importance were urban food system is now widely recognized as an important part of sustainable urban development (Doernberg et al., 2019; Osslon, 2018; Schulterbrandt Gragg et al., 2018). There is an urgent need to change the dominant model of agriculture production (Pingali et al., 2019) with a paradigm shift towards food consumption management. Pingali et al., 2019 suggest 'food systems approach' as an opportunities to strengthen the linkages between agriculture production and consumption pattern. FAO refers to improve the local management of food systems where cities can play an important role and has suggested four pillars of sustainability under sustainability assessment of food and agriculture (SAFA) framework (FAO, 2014). Aubry and Keber (2013) suggested short supply food chain and promotion of urban agriculture in Paris and surrounding area. "Alternative food chain" provides proximity relations between producers and consumers through a niche market. Shorter food chain also increases the accessibility of fresh food (Olsson, 2018) within the city premises. Agarwal & Sinha, 2017 have focused on urban farming from recycled water, thus optimizing the urban WEF nexus. Through systematic analysis, nexus approach has been used in quantifying the linkages and interactions involving water, energy and food productions (Adebiyi et al., 2020). City region food systems have been considered as central in the urban sustainability "transitions" as well as implementation of multiple goals of sustainable development (Olsson, 2018). Schulterbrandt Gragg et al., 2018 suggested a multidimensional approach for food system management by applying urban-WEF nexus framework.

Along with urban agriculture, managing food wastes at consumption level has been gaining momentum for sustainable urban development and addressing WEF nexus issues (Kibler et al., 2018). Food loss occurring at the end of the food chain, mainly at retail and consumption level, has been termed as "food waste" (FAO 2011, 2013; HLPE, 2014). Food waste is not an absolute quantity but has social, environmental and economic dimensions attached to it (Dagiliūtė & Musteikytė, 2019) and is recognized as an important issue among governments, academia, researchers and other stakeholders. The literature suggests that food wastes at urban level are managed through reducing avoidable food wastes (Covarrubias, 2019; Fodden et al., 2018; Terrapon-Pfaff et al., 2018), recycling by making compost from food wastes (Balaji & Arshinder, 2016; Hannibal & Vedlitz, 2019; Hussein et al, 2017; Liu et al., 2016) and producing energy from wastes (Adhikari et al., 2014; Walker et al., 2014; Balaji & Arshinder, 2016; Veldhuis et al., 2019). Feng et al., 2020 suggest for "Food-energy-water-wastes (FEW2)" system to manage waste to energy in the Hunter Region of Australia. Kibler et al., 2018 propose "food waste systems" for resource optimization within the WEF nexus framework.

Parameters affecting food management in urban areas and its linkages with WEF resources are summarized in Table 1.

Thus, we reviewed the literature and compiled six parameters within the framework of WEF nexus that have an impact on urban food management as a whole. The parameters include urban/peri-urban agriculture (UA/PUA), green roofs technology (GRT), urban farmer market (UFM), reducing avoidable food wastes (RFW), compost from food wastes (CFW) and energy from food wastes (EFW). All parameters identified characterize the possible synergies, linkages and interconnectedness with WEF nexus (Table 1). Institutional linkages across different sectors are essential to incorporate the WEF nexus thinking. Urban food management strategies through appropriate policy intervention can increase the resilience of urban-WEF system.

3.2 Present policy framework for food management and gap analysis

To understand the food policies and management at different levels, India's food management cycle can be divided into two parts, namely upstream food management (production focused) and downstream food management (consumption focused) as shown in Fig. 3. There are separate institutions associated with different aspects of food management like production, processing, distribution, quality control, consumption and food waste management at consumption level. Ministry of Agriculture and Farmers' Welfare (MoAFW) is the apex institution for formulating rules and regulations related to agriculture production for India and has minimal role at urban level. Food Corporation of India (FCI) is the nodal agency to deal with execution of various upstream food policies and related schemes of central government of India and comes under the Ministry of Consumer Affairs, Food and Public Distribution. FCI looks after the upstream food management including purchase, storage, transportation, movement and distribution. Most of the food wastage in developing countries like India occurs at this level as compared to food consumption level (FAO, 2014; Huang, 2020).

Downstream food management is consumption focused and includes food quality monitoring, distribution and consumption in urban and rural areas. Food Safety and Standards Authority of India (FSSAI) is an authority under the Ministry of Health and Family Welfare (MoHFW) that deals with quality management and standards related to food consumption. The major function of FSSAI is to lay down science-based standards for articles of

Table 1 Parameters affecting food management in urban areas and its WEF linkages

Parameters affecting food management in urban areas	Description	Impact on WEF nexus			References
		W	E	F	
Promoting urban/peri urban agriculture (UA/PUA)	Use of treated waste water for agriculture improves the availability of fresh produce, in the urban areas, thereby, reducing energy in transportation and also improves the liveability of city	✓	✓	✓	World Bank (2013); Miller-Robbie et al. (2017); Mohareb et al. (2017); Olsson (2018); Schulterbrandt Gragg et al. (2018); Pingali et al. (2019)
Green roofs technology (GRT)	Reduces energy demand during peak season-regulate microclimate, vegetables can be grown and consumed by household	✓	✓	✓	Engstrom, et al. (2017); Al Zu'bi and Mansour (2017); Lehmann (2018)
Urban Farmer Market (UFM)-Shortening food supply chain	Reducing energy in transportation and also improves the liveability of city	x	✓	✓	Aubry & Kebir (2013); Olsson (2018)
Reducing avoidable food wastes (RFW)	New cooking recipe with leftover food	✓	✓	✓	Foden, et al. (2018); Terrapon-Pfaff et al. (2018); Covarrubias (2019)
Compost from food wastes (CFW)	Reducing and managing food wastage at social gathering (wedding, parties, *bhandaras*) and household level; using household organic waste as a nutrient supplement in parks management or in agriculture, composting organic wastes (less wastes to landfill sites)	✓	x	✓	Liu et al. (2016); Balaji & Arshinder (2016); Hussein et al. (2017); Hannibal & Vedlitz (2019)
Energy from wastes (EFW)	Biogas generation from food waste and scalability of waste to energy technology leads to reduced dependence on conventional source of energy, recover energy by food waste treatment	x	✓	✓	Veldhuis et al. (2019); Feng et al. (2020)

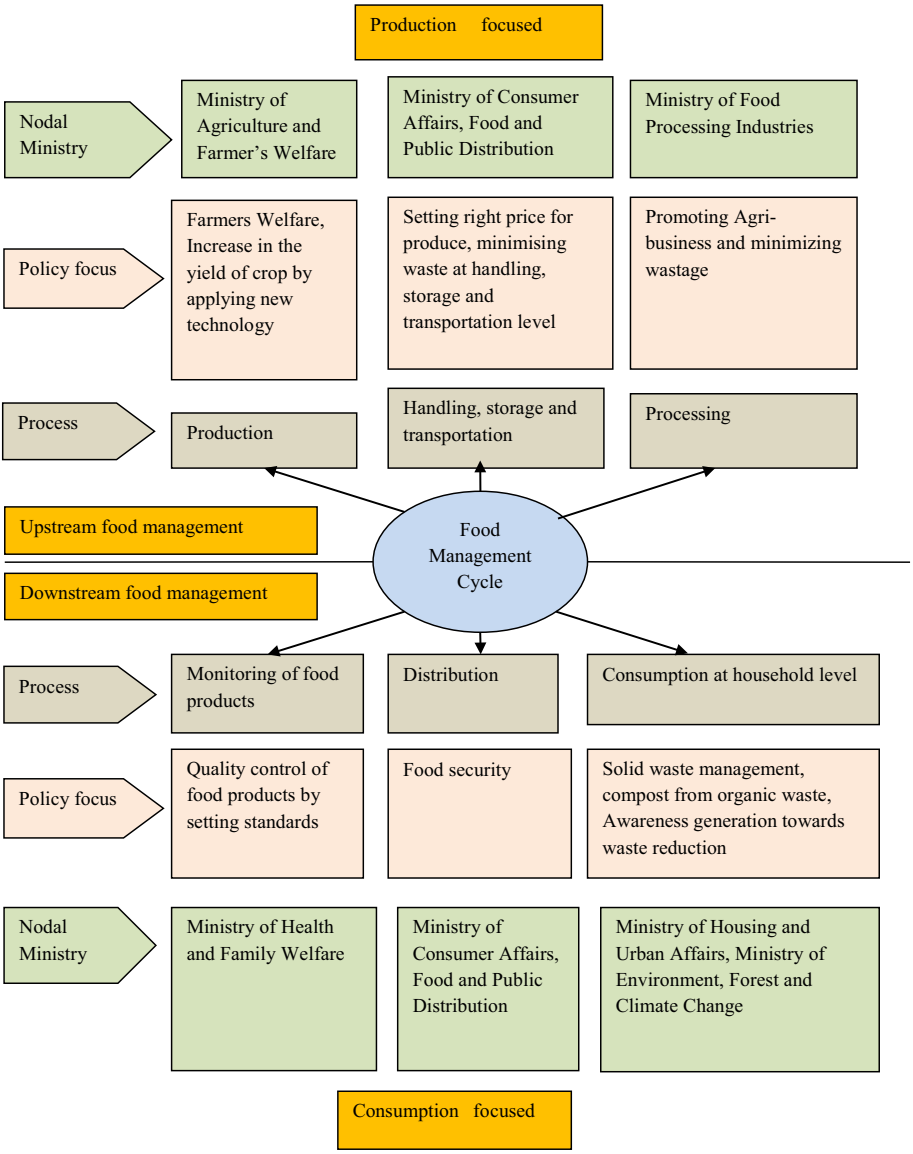

Fig. 3 Food cycle management and policy focus in India

food and to regulate manufacturing, storage, distribution to ensure availability of safe and nutritious food for the consumption of food (FSSAI, 2006). Ministry of Housing and Urban Affairs (MoHUA) is nodal Ministry for urban development in the country including water supply, sanitation and municipal solid wastes management including food wastes. Ministry of Environment, Forest and Climate Change (MoEF&CC) through its various plans and policies have been playing a very important role in optimizing water, energy and food inter linkages at urban level. The Municipal Solid Waste Management Rules were revised and

passed in 2016 for the effective management of solid wastes being generated at city level. The Rule mentions about the reduce, reuse and recycling of organic wastes collected from household, waste to energy generation as well interdepartmental coordination for better implementation (MoEF&CC Notification, 2016).

In India, both management and legal aspects concerned with water, agriculture and urban matters are under the responsibilities of State Governments, whereas matter pertaining to energy and foodstuffs trading is shared by both Central and State Governments.

Urban development is the responsibility of State and Centre can issue only directives to States. Thus, the resulting WEF issue management in urban context is very fragmentary since these four sectors are under the jurisdiction of different authorities. With the objectives of managing the water, energy and food resources, Government of India has enacted different legislations, guidelines, schemes and programs that fall under the responsibilities of various ministries at national and state level. For the purpose of the study, totally 34 different documents at national level were analysed deeply to find parameters identified for urban food management strategies, and it was found that only 10 documents across five different sectors (water, energy, food, urban and environment) covered various issues separately in the context of urban food management (Table 2). As evident from Table 2, six parameters identified are addressed by different sectors separately. We found that there is provision for urban food management strategies related to food wastes management in the energy, environment and urban sectors. Except for urban/peri-urban agriculture, all other five parameters, namely, GRT, UFM, RFW, CFW and EFW, have been addressed, though in fragment by different sectors. Urban sector addresses maximum number of three parameters (green roof technology, compost from food wastes and energy generation from food wastes) through their different programs and schemes.

We did not find any of the identified parameters being addressed by water sector though water policy encourages the reuse of urban water effluents from households (NWP, 2012) which provides a scope to use waste water for urban and peri-urban agriculture.

Urban or peri-urban agriculture is mostly viewed in the context of food security and poverty alleviation (World Bank, 2013) in the developing countries, but the role it plays in optimizing the water, energy and food inter linkages still needs attention. Urban and peri-urban agriculture, particularly in the context of developing countries, plays a crucial role in diversifying urban diets and providing environmental services in urban and peri-urban areas (Nambi et al., 2014; World Bank, 2013). In context of India, urban and peri-urban agriculture still remains an informal sector and requires strong political commitment to integrate it into policy levels. Significant amount of water and energy is consumed in transporting food into the city region (World Bank, 2013). Food loss and wastage can be reduced significantly by shortening the food supply chain from production to consumption at city level (FAO, 2015). The analysis of different programs, policies and schemes across four different sectors revealed that UA/PUA has not been the policy focus of the government (Table 2). The Government had launched a scheme on "Vegetable Initiative for Urban Clusters (VIUC)" in the 12th Five Year Plan for addressing concerns related to demand and supply side of vegetables, enhancing productivity and encouraging establishment of efficient supply chain in urban and peri urban clusters (Ministry of Agriculture & Farmers Welfare, 2013), but still robust and holistic city-level policies and plans to promote urban agriculture are needed. There is a scope of supporting and addressing urban agriculture under various schemes and programs of MoHUA. For example, there is a provision for development of "Green Space" under Atal Mission for Rejuvenation & Urban Transformation (AMRUT) and "Greenfield Area Development" under the Smart Cities Mission (SCM).

Table 2 Different programs/policies/schemes addressing the identified parameters for urban food management in India

Policies/programs/guidelines/schemes	Sector	Urban food management parameters identified*					
		UA/PUA	GRT	UFM	RFW	CFW	EFW
National Electricity Policy, 2005	Energy	x	x	x	x	x	✓
Green rating for integrated habitat assessment (GRIHA), 2015	Energy	x	✓	x	x	x	x
National Mission for Sustainable Agriculture, 2010	Food	x	x	✓	x	x	x
National Mission on Sustainable Habitat, 2010	Urban	x	x	x	x	✓	✓
Urban Greening Guidelines, 2014	Urban	x	✓	x	x	x	x
Smart Cities Mission, 2015	Urban	x	✓	x	x	✓	✓
Urban and regional Plan formulation and Implementation guidelines, 2015	Urban	x	✓	x	x	x	x
Model Building Byelaws (MBBL)-2016	Urban	x	x	x	x	✓	x
National Action Plan for Municipal Solid Waste Management, 2015	Environment	x	x	x	x	✓	✓
Solid Wastes Management Rule, 2016	Environment	x	x	x	x	✓	✓

*Identified and explained in Table 1 (UA/PUA = Urban agriculture/Peri-urban agriculture, GRT = Green roof technology, UFM = urban farmer market, RFW = reduce food wastes, CFW = compost from food waste, EFW = energy from food wastes)

Sustainable urbanization is inextricably linked to food waste and its management. Food waste is a global issue today and different countries have taken steps to address this issue either through social reforms, technological options and/or regulatory and policy approach (Liu et al., 2016; Mourad, 2015). Urbanization has amplified the wastage of food as most of the food is uneaten at the consumption level (FAO, 2011; Liu et al., 2016). India wastes approximately 67 million tonne of food every year which is valued to be loss of Rs 92,000 crore, nearly two-thirds of cost to feed 600 million poor people with subsidized ration under the National Food Security Program (Haq, 2016). Food waste is a burden on urban local bodies as it amounts for maximum volume of the total waste generated at household level. According to a report of NITI Aayog on waste to energy, organic wastes constitute 51 percent of the total volume of municipal solid wastes in India (Niti Aayog, 2014).

The Government of India has taken significant measures to handle upstream food loss and wastage (harvesting, storage and transportation), but downstream food wastage (consumption) mostly ends up going to the landfill sites. There is the provision to manage waste after it is generated through Solid Waste Management Rules, 2016, and Ministry of Environment, Forest & Climate Change is the nodal agency, responsible for overall monitoring and implementation of the Rule in the country. But major drawback lies at the implementation level. The rule also talks about framing of National Policy on Solid Waste Management by Ministry of Housing and Urban Affairs, but such policy has not been developed till yet.

Government policies related to food management are focused on upstream food management mostly related to production and related activities. Downstream food management, in particular food consumption at urban level, needs attention. A paradigm shift is required towards holistic and integrated urban food policy. India is a vast country with 34% of population residing in the urban areas (MoHUA, 2019) and is projected to reach 50% by 2050. This provides a dynamic environment for the development of legislations and policies related to management of water, energy and food involving many stakeholders at different level.

4 Discussion

In this part, we explored the broad implications of this study for sustainable food management and its relevance for the Global South regions. We also discussed about the significance of our findings in the context of Sustainable Development Goals and suggested a framework for wider applications.

4.1 Framework for Sustainable food management at urban level: Relevance and Recommendations

Today, the world is having more urban population than ever, with 55% of global population living in the cities of different types and is expected to increase by 68% by 2050 (Nations, 2018). According to the United Nations report, 90% of this increase in the urban population is taking place in the Asian and African countries belonging to Global South regions (Nations, 2018). This massive urban agglomeration has resulted in significant socioeconomic and environmental changes, surpassing carrying capacity and putting additional strain on the region's natural resource base (Meadows et al., 1974; Miller-Robbie et al., 2017; Rees, 2018). By 2050, this growing global population would require 60% more food,

50% more energy by 2035, and irrigation would need 10% more water than it does now (FAO, 2014; Swatuk & Cash, 2018).

As the world becomes more urbanized, successful urban growth management becomes increasingly important for long-term development. The WEF nexus has become a widely acknowledged framework for integrated resource planning, usage, and management for long-term development, particularly in the developing countries of Global South, which faces resource constraints as well as threats of climate change (Lehmann, 2018; Yung et al., 2019). The literature provides with sufficient evidence for enhancing food from production perspective through nexus framework. However, comprehending the relevance of the WEF nexus from the perspective of food consumption in urban areas is still in its infancy (Ilieva, 2017). Despite increasing urban growth rates and high levels of urban food insecurity in Africa, there has been little comprehensive examination of food systems capable of restoring the complexity of the variables that act within city boundaries (Bini et al., 2017). This is the most significant gap that needs to be bridged in order to turn the nexus into a fully functional operational framework with policy implications. Given the issues that today's society faces, food systems play a critical role in enabling sustainable and resilient cities to emerge.

A framework for holistic food management at urban level is recommended which has been categorized at two levels namely, supporting city region food systems and managing food wastes at city level/household level as shown in Fig. 4. The study categorizes the city region food system into three parts, namely urban and peri-urban agriculture (UA/PUA), green roofs technology (GRT) as well as urban farmers market (UFM). UA/PUA finds its applicability in optimizing WEF nexus by using treated sewage water for agriculture which in turn increases the availability of fresh produce in urban areas, reduces energy in transportation (Bini et al., 2017; Miller-Robbie et al., 2017; Mohareb et al., 2017; Olsson, 2018; Pingali et al., 2019) and thus improves the liveability of the city (Schulterbrandt Gragg

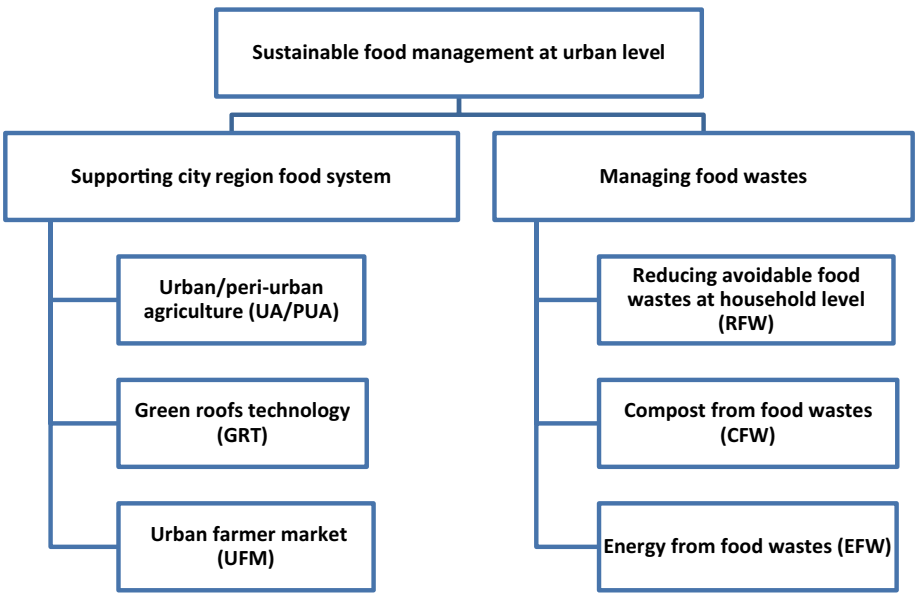

Fig. 4 Framework for Sustainable Food management at urban level

et al., 2018). Under GRT, vegetables can be grown and consumed by households. Along with meeting the fresh food demands, GRT reduces energy demand during peak season and thus regulates microclimate of that region (Al Zu'bi & Mansour, 2017; Engstrom et al., 2017; Lehmann, 2018). UFM supports the shorter food supply chain that maintains the integrity of fresh foods and also reduces energy in transportation (Aubry & Kebir, 2013; Olsson, 2018).

Another category identified is managing food wastes, which is also divided into three parts, namely reducing avoidable food wastes (RFW), compost from food wastes (CFW) and energy from wastes (EFW). To explore the synergies of WEF resources at household level, Foden et al., 2018 introduced the concept of "nexus at home". Home practices like new cooking recipe with leftover food, using sink plug to fill kitchen sink before cleaning utensils, using kitchen waste water for other purpose like gardening, washing vehicle, cleaning lawn, etc. contribute to sustainable kitchen habits and also leads to WEF resources management (Covarrubias, 2019; Foden et al., 2018; Terrapon-Pfaff et al., 2018). Reducing and managing food wastage at social gathering and household level can help in reducing avoidable food wastes. This confirms with the findings of Hannibal and Vedlitz, (2019), on "organizational food waste" in the USA, and result showed that awareness of the interrelationship between food–water and food–energy is significantly related to food waste concern and thereby policy preferences to reduce food wastes.

The study suggests CFW as one of the strategies under managing food wastes category. Household organic wastes can be used as a nutrient supplement in parks management or in agriculture (Hannibal & Vedlitz, 2019; Hussein et al, 2017; Liu et al., 2016) and will also reduce burden of the landfill sites (Balaji & Arshinder, 2016). Biogas generation from food waste (EFW) and scalability of waste to energy technology lead to reduced dependence on conventional source of energy (Feng et al., 2020; Veldhuis et al., 2019). Therefore, it is recommended that food management must be considered as an integral part of urban development missions (Tayal & Singh, 2016) in the developing nations of Global South. Considering the linkages of food with water and energy, it is pertinent to develop smart solutions to ensure effective supply, storage, distribution and marketing mechanisms, simultaneously, ensuring optimum food consumption patterns at household level in cities and towns. A combination of food management schemes with urban development missions will facilitate sustainable development of urban areas by ensuring optimization of resource use.

We discussed a "Framework for Sustainable Food management at urban level" in this research. This framework presents a potential approach for accomplishing SDGs as well as gaining a better knowledge of the untapped potential for building integrated food management strategies. Therefore, implications of the WEF framework from urban food consumption point are very pertinent, which increases challenges as well as opportunities for optimal resource use, especially for the developing nations of the Global South regions.

4.2 Linking urban food management strategies with Sustainable Development Goals (SDGs)

The parameters identified under sustainable urban food management are helpful in addressing multiple goals of sustainable development either directly or indirectly as shown in Fig. 5. UA and PUA improve the availability of fresh produce in the urban areas (SDG 2, 11), can use treated waste water for agriculture (SDG 6), reduces energy in transportation (SDG 7) and thus improve the liveability of city (SDG 13) as well as support good health and well-being (SDG 3) by providing fresh and healthy food. GRT Reduces energy demand during

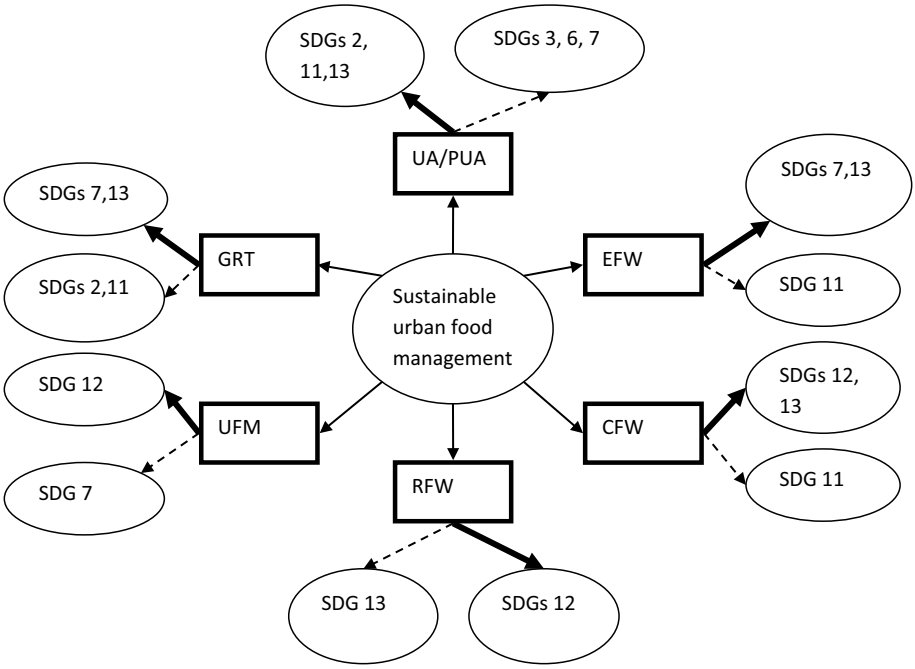

Fig. 5 Sustainable urban food management and its linkages with Sustainable Development Goals (Dark arrow shows direct linkages, dotted arrow shows indirect linkages)

peak season (SDG 7), regulates microclimate (SDG 13) and vegetables can be grown and consumed by household (SDG 2) and makes the city resilient as well (SDG 11). UFM reduces energy in transportation (SDG 7) and reduces food losses along production and supply chains (SDG 12). RFW through new cooking recipe with leftover food and managing food wastage at social gathering and household level is a way towards sustainable consumption habit (SDG 12). Making compost (CFW) using household organic waste can serve as a nutrient supplement in parks management or in agriculture (SDG 11, 12) and reduces burden on landfill sites (SDG 13). Producing energy from waste (EFW) leads to reduced dependence on conventional source of energy (SDG 7) and thus addresses climate mitigation (SDG 13) and makes the city liveable (SDG 11).

Thus, looking into the trend of growing urban population, promoting the coordination of food policies with other sectors including water and energy is strongly recommended. The study demonstrates that WEF sectors policies should be developed and implemented as an integrated part of urban nexus policies. Studies suggest as well as supports that cities can play a pertinent role in developing resilient food systems (Doernberg et al., 2019; MUFPP, 2015) and provide a way forward for sustainable urban development. The urban-WEF nexus approach explored in this study provides action-oriented prospects for supporting the growing urban population with limited resources available.

5 Conclusion

The nexus framework has been recognized and finds applicability across different sectors. But it has not been addressed comprehensively at urban level in developing countries context. In the rising trend of urbanization and interdependencies between water, energy and food resources, the urban-WEF framework provides an imperative way forward for optimal resource use and offers opportunities to address the agenda for sustainable urban development in a more holistic way. Using India as a case, the study showed that management of WEF resources at food production as well as consumption level is complex because of involvement of many stakeholders. Given the governance of WEF resources is complex at urban level, any shift towards more sustainable management of resources will need to focus on the network of actors for its successful implementation.

From food policy point of view and nexus, understanding elucidates that integrated urban food policies and its implementation through planned document need attention of the policy makers. As evident from the analysis of various government documents, the policy focus is more in solid waste management either through making compost or generating energy from the waste. City region food system has not been looked as an integral part of urban development and role it plays in optimizing water and energy needs more empirical research. This is due to the problem-centric approach for managing urban food strategies. The potentiality of integrated urban food management systems is still underexplored and provides an opportunity for empirical-based research in this domain.

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