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A tale of service regimes in irrigated urban agriculture: evidence from two cities in the Global South

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ABSTRACT

This paper presents a service regime perspective on irrigated agricultural practices and their governance in cities of the developing world. Findings of the governance of irrigated urban agriculture and adjacent practices in Arusha (Tanzania) and Khulna (Bangladesh) show how service regimes bridge the gap between (formal) governance institutions and practices around irrigated urban agriculture. They cross-cut the different institutional layers in urban society and boundaries between agricultural and urban water systems. By acknowledging, facilitating and aligning service regimes, scholars and practitioners can strengthen governance arrangements for enhancing irrigated urban agriculture while safeguarding water quality and food safety.

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Irrigated urban agriculture; service regimes; practices; Arusha; Khulna

Introduction

In the face of population growth, urbanization and climate change, urban water systems are in need of adaptations and redesign to achieve food safety and circularity. Agricultural production may benefit from the reuse of urban water (be it direct or indirect, from surface run-off, rivers, drainage or sewer canals, ponds or wells) and thereby contribute to circular urban water management. The use of urban water sources for irrigated urban agriculture is already commonplace in many African and Asian cities, but in scattered and unplanned ways (De Bon et al., 2010; Drechsel et al., 2010; Haldar et al., 2022a; Janeiro et al., 2020; Miller-Robbie et al., 2017; Thebo et al., 2017). Urban agriculture contributes to local food security and employment opportunities by tapping into urban water networks and producing in, around or downstream of growing cities. Despite experiencing constant pressures – such as the threat of displacement by city authorities, lack of clarity about land ownership, urban growth, polluted waters, negative

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health impacts and cultural taboos – agriculture shows persistence in urban and peri-urban areas.

If water reuse – and ultimately circularity of water and nutrient flows – in urban agriculture is aspired, there is a need to better understand current practices of irrigated urban agriculture (IUA), how they persist despite the pressures mentioned and how they could be supported. Urban agriculture has been extensively studied by a variety of disciplines targeting agronomy, food security, urban planning, informality or community participation (Contesse et al., 2018; Crush et al., 2011; Lee-Smith, 2010). In a similar vein, wastewater irrigation (either direct or indirect) has been the object of extensive studies of environment and health, drainage and irrigation engineering (Drechsel et al., 2010; Evers et al., 2010; Huibers & Raschid-Sally, 2005). Yet, we observe a gap in knowledge about (1) why and how urban and peri-urban farmers make use of available urban water flows, and (2) whether and how urban planners, water managers and urban governors take farmer's practices into consideration in urban policy and planning.

These are admittedly extensive grounds to cover in a paper. Yet with this contribution we aim to understand the IUA practices of urban farmers on the ground and cover the way they are supported or hindered by the actors and institutions, their policies and measures at multiple levels of urban governance. As 'urban agriculture' is a term used for many farming practices in an urban and peri-urban context, we specify our scope in this paper to IUA, referring to 'all agricultural practices in urban areas that use any form of urban water for crop cultivation' (Veldwisch et al., 2024) in both urban and peri-urban areas. By characterizing IUA based on locational aspects, we also acknowledge the tenure arrangements and development status of these vacant areas. We explicitly highlight the irrigation aspect of urban agriculture, as agriculture and the city are often interconnected through water. This paper aims to provide a new perspective on IUA practices and its governance in cities of the Global South, as to inform both scholars and practitioners about the ways in which urban water is part and parcel of such practices and about how to strengthen governance arrangements for enhancing the circularity in urban water management.

The paper is organized as follows. First, we introduce the theoretical perspective that allows us to make the connection between IUA practices and urban governance. We build on geographical and sociotechnical understandings of urban infrastructures and use the Multilevel Governance Perspective (Geels, 2002) added with the concept of 'service regimes' by Van Welie et al. (2018). Service regimes form the space for continuous interaction between everyday production and consumption practices and the governance arrangements around sectors such as urban water provision, or food and agriculture. Next, the methodology section presents how we investigated these practices and service regimes with the help of field studies conducted in two urban conglomerates, namely Arusha, Tanzania and Khulna, Bangladesh. Both cities show ample evidence of IUA over a long period of time, although they are very distinct in social, cultural and physical–geographical respects (Table 1). The results of this research will show how irrigated urban agriculture practices are embedded in wider bundles of practices of sanitation and marketing of food and in wider regimes of urban water and agriculture. We subsequently discuss our findings against the background of contemporary literature on multilevel urban governance and integration and conclude by answering the questions on practices of IUA and how they are performed and being governed in both cities.

Table 1. Summarizing characteristics of sector and service reginmes and UIA practices in Khulna and Arusha.

Characteristics of Water and Agricultural Sector Regimes	Khulna	Arusha
	Formal institutions, policies and infrastructures	
Sector regimes for irrigated urban agriculture in Khulna and Arusha	Khulna Water and Sewarage Authority, Department of Environment; formal legislation, (but poor enforcement) for land-use, sanitation, food production	Arusha Urban Water supply and Sanitation Authority and the municipal Urban Planning, Health and Environment and Agricultural departments; formal legislation for land use, sanitation, food production, poorly enforced
Service Regimes	Whole of the following agricultural, sanitation and food marketing practices, materials and (informal) rule sets in place:	
Irrigated urban agriculture practices in Khulna and Arusha	At semi-secured spaces in the peri-urban areas connected to drains: • Producing rice and seasonal vegetables • Regularly pumping polluted water from rivers and drains, aware of health risks	At open spaces along river sides: • Producing leafy vegetables • Irregular and manually pumping and applying contaminated river water, low risk awareness
Sanitation practices in Khulna and Arusha	Manually discharging sludge in drains	Use of floods to empty latrines
Marketing practices in Khulna and Arusha	Directly selling produce at local markets	Daily production sold at semi-wholesale markets

Theoretical perspective

Analysing IUA in cities of the Global South requires a theoretical perspective that covers the scalar and sociotechnical diversity in existing water infrastructures and, secondly, the multiple levels of governance involved in enabling or hampering its development. The past decade has seen the emergence of new approaches to analyse urban infrastructure provision and governance in cities of the Global South (Cherunya et al., 2020; Lawhon et al., 2018; Letema et al., 2014; Silver & Marvin, 2017; Van Welie et al., 2018), which all acknowledge the diversity of urban infrastructure provision. Using the analytical lens of so-called 'Heterogeneous Infrastructure Configurations', Lawhon et al. (2018) studied 'geographically spread socio-technological configurations: configurations which might involve many different kinds of technologies, relations, capacities and operations, entailing different risks and power relationships' (p. 720). Their analysis hence moves 'beyond debates over state, community or private ownerships, as well as formal or informal infrsatructures and towards comparatrive thinking about the conditions of possibility for incermental change' (p. 722). Diversity in scales of water infrastructures, sources of water, levels of management and user involvement in cities of the Global South have also necessitated the development of a so-called Modernized Mixtures approach (Letema et al., 2014) in analysing systems of water, sanitation and waste in East African urban centres. This approach typically sheds light on the intermediate positions between 'modern', large-scale and centrally managed infrastructures on the one hand and the low-tech, community-based, sociotechnical configurations for urban water service provision on the other.

As valuable as these approaches are in acknowledging social and technical diversity in systems of urban water provision and in presenting the analytical tools to assess them, such

approaches are less equipped to analyse prevailing governance of urban water configurations and water using practices in urban centres of the Global South. For this, we need to widen our scope towards the multiple levels of governance that come to play in urban water governance. The Multilevel Framework of Geels (2002) partly serves that purpose, as it enables an analysis of the urban water sector as a relatively stable sociotechnical regime (encompassing Markets, User Preferences, Science, Policy, Technology and Culture), nested between Niche Developments (small-scale and protected test grounds for innovation, such as controlled wastewater reuse) and a Sociotechnical Landscape, which 'refers to aspects of the wider exogenous environment that affect socio-technical development' (p. 451), but cannot be changed easily in the shorter term. Here we can think of the geographical setting and socioeconomic and political status of a city. In case of urban water sector regimes, such a view is geared to identify Sanitation, Water and Sewery Departments, large networks of drinking water and sewerage provision and the national regulatory systems for water management and supply as 'regime'. Although these elements of water sector regimes do exist in the Global South, only focusing on these would exclude most of the intricate connections between such formal institutions and the ways water is utilized, consumed and discharged in day-to-day water practices of farmers, water vendors, householders or sanitation workers in urban settlements.

To cover this gap, Van Welie et al. (2018) reconceptualized sociotechnical regimes related to the heterogeneous contexts we can find in cities of the Global South. They distinguish 'sectoral regimes' from 'service regimes', in which the latter 'form around specific institutionalized combinations of technologies, user routines, and organizational forms for providing the service' (p. 261). The term 'sectoral regimes' then refers to 'broader economic and societal realms (or organizational fields) that cover a societal function like transport, food, safe urban water, electricity, and so forth' (p. 261). The relation between sector regimes and service regimes is mostly hierarchical, in which several service regimes may fall under a single sector regime. For instance, Van Welie et al. (2018) identified five sanitation service regimes under Nairobi's sanitation sector regime, ranging from *domestic sewer regime* to *container-based (toilets) regime*, none of which being dominant or aligned with one another. The service regimes are all described and analysed on their infrastructural, organizational and temporal–spatial aspects, as well as on their meaning for users and service providers and the social interactions they envoke. All of these aspects relate to how services are incorporated in routinized social practices around sanition. Analysing IUA within cities of the Global South in this way covers both the various formal as well as informal water managing actors, infrastructures and rule sets that connect the water and agricultural sector regimes with everyday IUA and sanitation practices in urban settings. By understanding the service regimes connecting IUA practices and formal water and agricultural sector regimes, we are better equipped to show how practices of IUA can be supported in providing secure livelihoods for farmers and safe and sufficient food for the urban population at large.

Building on this general understanding of societal and infrastructural diversity and dynamics, we built a specified framework for the case of IUA (Figure 1) based on three levels: practices, service regimes and sector regimes. In this paper we situate *irrigation practices* in urban agriculture within a particular *service regime* of IUA, which is again situated under the *sector regimes* of both agriculture and urban water: providing food, income and other benefits to people residing in and around cities. Practices of IUA (irrigation and cultivation) are visualized together with adjacent practices of sanitation (dealing with wastewater and drainage

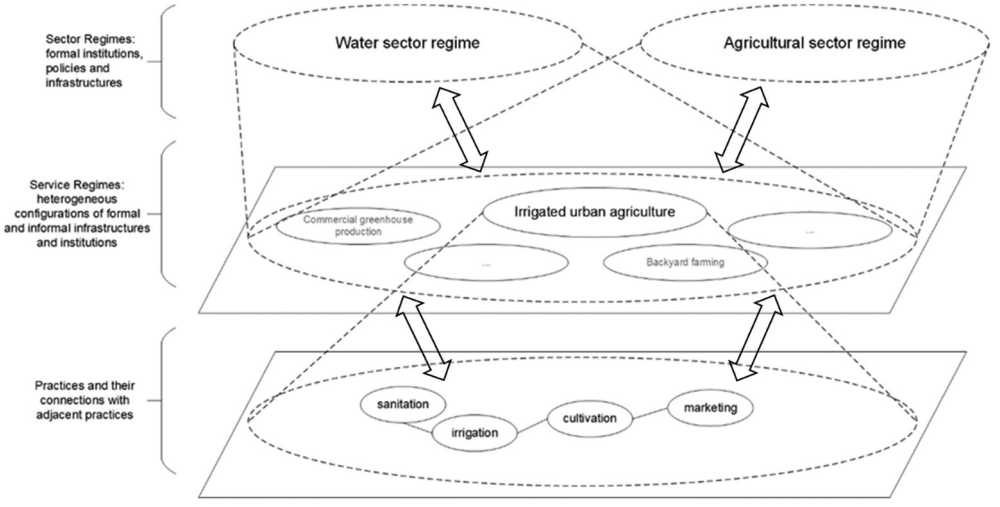

Figure 1. Interrelationships among practices, service regimes and sector regimes (adapted to irrigated agriculture, based on Geels (2002) and Van Welie et al. (2018)).

water) and food marketing (dealing with agricultural produce from IUA farming). In any city it is expected that there are several recognizable sociotechnical and governance configurations around IUA, which can be studied independently as *service regimes*.

In this article, we study smallholder IUA in two different geographical settings. Within each city, the practices that we recognize still hold a level of diversity based on its sociomaterial context. Other types of agriculture, such as backyard gardening or greenhouse production, do also take place and fall under the same sector regimes but within different service regimes.

Methodology

To understand IUA practices and service regimes, field work was carried out in the urban and peri-urban areas of Khulna, Bangladesh and Arusha, Tanzania (Figure 2). Khulna is the third largest city in Bangladesh and is the administrative centre of the region, accommodating more than 900,000 inhabitants. The main city area comprises of an area of 45 km^2, which is governed by the local municipal council. The adjacent areas of the city are agricultural in nature and are expected to transform into built-up areas over time. Being a delta city, Khulna has been confronted with climate change-induced natural disasters such as heatwaves, cyclones and floods. These events are challenging the farmers of the region to sustain their livelihood. Many farmers originally migrated from climate-vulnerable areas of the coastal region who lost their livelihood due to climate change impacts.

Rice and seasonal vegetables production, located mostly in the peri-urban areas of Khulna, provides farmers the means to survive, even though they are also involved in other occupations to maintain their livelihood. Farmers rely on surface water for irrigation, especially during dry periods between January and April. Saltwater intrusion and discharge of untreated wastewater into the surface water restricts access to clean water for irrigation, which is crucial for food production (Haldar et al., 2021). Farmers are forced to use this source due to lack of

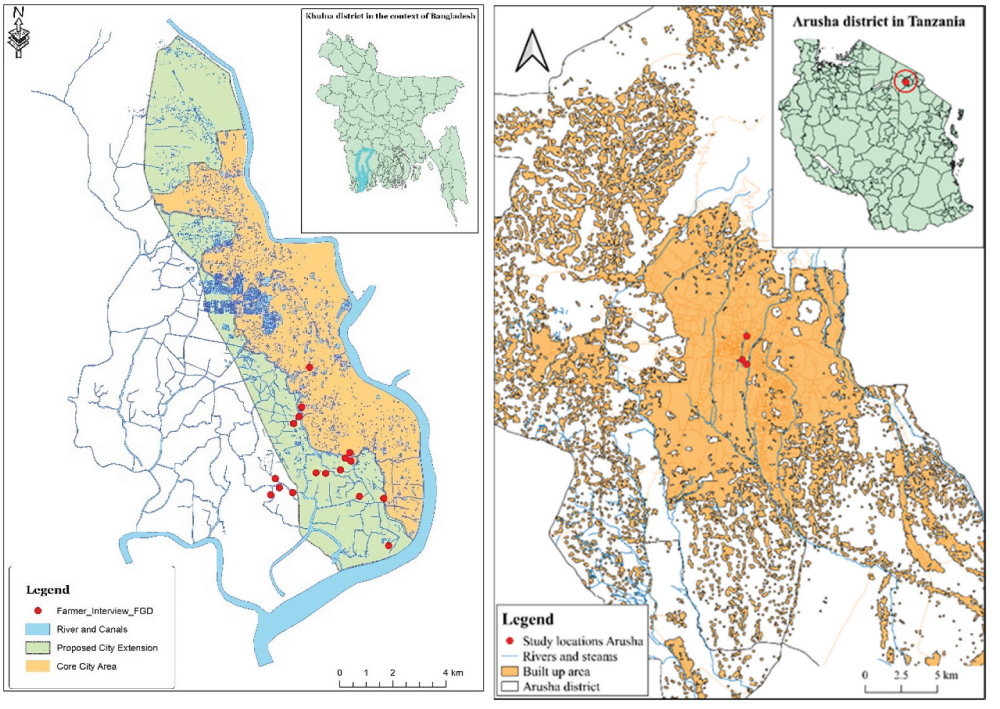

Figure 2. Maps of case study areas in Khulna (left) and Arusha (right) (constructed by authors).

alternative sources, resulting in indirect wastewater irrigation which has become a common practice in the city and surrounding areas (Haldar et al., 2022b).

The other urban conglomerate, Arusha, is the third largest city of Tanzania with an estimated population of over half a million in 2022. The city is located in the north of the country in the direct vicinity of Mt Meru, a dormant volcano. The city and its surrounding landscape are characterized by mountains and undulating hills with rich soils and an abundance of springs and mountain streams. A rich culture of IUA practices pre-dates European colonization and is still vibrant in the rural areas surrounding the city (De Bont et al., 2016; Spear, 1996) but also in the (quickly) expanding outskirts of Arusha. Even closer to the centre of the city, people have developed irrigation in diverse urban contexts with a variety of irrigation practises (De Raat, 2018; Thomas et al., 2021a).

In Arusha, 80% of the area covered by the city is unplanned and 86% of the people live in informally developed settlements (Abwe, 2019). Most farmers in the areas belong to the low-income social category of city dwellers, and many are migrants from outside Arusha city who have come in search of livelihood opportunities and found vegetable farming as a venture for improving their livelihoods. In the open spaces within the urban built-up areas of Arusha, the production of vegetables is most common.

Both cities serve as examples of cities where irrigated agriculture is common within and around the urban settlements. In terms of geographical, political and cultural contexts, the cities widely differ. The analysis in this paper builds on research in both Khulna (Haldar et al., 2020) and Arusha (De Raat, 2018). Additional field research was conducted in both study areas between 2021 and 2022 through a variety of data collection

methods to understand the IUA practices, interlinkages with other urban practices and IUA as a sector itself. Field observations, individual farmer interviews, focus group discussions and key informant interviews with officials were conducted and policy documents analysed to understand and construct service regimes related to IUA in Khulna and Arusha.

At first, field observations were carried out in both study areas with the aim of gaining understanding of the irrigation practices in urban agriculture and to plan the necessary field work activities. Areas were identified for purposes of interviewing (groups of) farmers. For Khulna, the interaction with the farmers mostly took place in the southern part of the city as agricultural practices are highly aggregated in those areas due to the existence of numerous branches of rivers and canals (Figure 2). For Arusha, open spaces within the urban built-up areas that had a reliable source of water were found to be commonly used for agricultural practices. A total of 20 and 21 individual farmer interviews were conducted in Khulna and Arusha, respectively. Additionally, two focus group discussions (FGD) were carried out in Arusha and three FGDs in Khulna. Farmer interviews and FGDs aimed to understand the different typologies of urban agriculture and associated irrigation practices, possible service regimes as well as the distribution of constraints and benefits among the farmers. To achieve this, questions related to irrigation methods, sources of irrigation, crops cultivated, marketing of the crops, issues faced related to irrigation and cultivation and perception of the farmers towards the practice were included. During the on-site FGDs with five or six farmers in each session, the focus was on understanding motivations of farmers to adopt the current practices, next to the legal, social, institutional barriers and ways to overcome these barriers. They also reflected on current their irrigation, marketing and sanitation practices and long-term planning.

Next, key informant interviews (KII; seven in Khulna, eight in Arusha) were carried out involving government and non-government officials related to IUA irrigation practices. Officials were selected from different organizations that are responsible for IUA. The discussion with the officials focused on their perceptions and concerns about current practices, the role of institutions, availability of related policy documents and long-term planning to ensure safe irrigation practices.

Finally, policy documents were analysed to study governance of IUA at the city level. To this end the practices that we studied in particular locations are situated in the larger frame of service provision that together comprise the service regimes. Several policy documents were included in the analysis to identify the types of IUA that are deemed (un)acceptable and how they are supported and governed by formal institutions. For Khulna these included the Bangladesh Delta Plan 2100, Urban Sector Plan, Khulna City Master Plan, policy documents of Khulna Water Supply and Sewerage Authority (Government of the People's Republic of Bangladesh, 2001, 2008, 2014, 2018) and the National Water Management Plan (Government of the People's Republic of Bangladesh, 2001). For Arusha these included the National Water Policy, the Water Resources Management Act and the Tanzania National Irrigation Policy (URT, 2002, 2009, 2010).

Results

First, we address what Arusha and Khulna have in common in terms of IUA. Farmers in both cities base their practices on the availability of land, proximity to water sources and access to markets. This results in the commercial production of high-value agricultural products in small spaces of marginalized areas. In both cities, agricultural production is allowed to occur, as long as it does not become a nuisance for surrounding dwellers or will not be converted into built-up area. This ambiguity over the long-term existence of such spaces enables farmers to provide food services to the city. However, it also provides the scope for regulatory bodies to take action against such agricultural practices at any given moment. IUA is persistent in this way, but farmers remain with a limited say to construct secure spaces of productive and safe agriculture for the longer term. In both Khulna and Arusha, the IUA practices by smallholder farmers are built on long-term experience, which are persistent yet insecure in terms of tenure as well in terms of water quality and availability.

We present our case-specific findings according to the logic of Figure 1 starting with IUA practices and from there to adjacent practices and the significance of service regimes.

Irrigated urban agriculture practices

The three studied cases in Arusha (Themi, Naura and Sekei) represent a dominant mode of IUA with a clear pattern of engagement by governance institutions despite the formal illegality of IUA at these urban spaces. Our interviews and direct observations show that the areas along streams and rivers throughout Arusha have been cleared of bushes and taken into use for small-scale IUA. In interviews, farmers mentioned that government officials told them that they can use the areas temporarily despite formal rules prohibiting use of these areas (FGD, Themi, 18 May 2022; FGD, Naura, 19 May 2022). Perennial crops are not allowed (emphasizing that it is temporary use) and trees should not be cut down (as this may harm the stability of the riverbanks). The irrigated production on the riverbanks is mostly market-oriented and focuses on the production of green leafy vegetables such as *Mchicha* (amaranthus) and *Sukumawiki* (collard). Leafy vegetables are popularly grown in the city given that insecure tenure arrangements favour production systems with short growth cycles and low capital investments (Thomas et al., 2021a). Water is taken from the streams either with buckets and watering cans or with small pumps. Both land and water rights are locally arranged and, in many cases, insecure. The practice in Arusha is dominated by female farmers (about 80%), who in most cases are married but whose husbands do not participate in the farming activities. Help by other household members, particularly children, does occur and there is incidental hiring of labour power from young men, for instance, as explained in a group discussion:

> You know we basically have a lot to do here, so we normally hire men to assist us with cultivating plots while we do other things such as taking crops to the market, planting, watering, etc. (Focus group discussion, Naura, 19 May 2022)

In the Themi area farmers jointly operate and utilize a traditional earthen canal that diverts water from the Themi river further upstream. Farmers irrigate their plots on

alternation basis, especially during the dry season where water is scarce as one of the farmers noted:

> we normally make rotations of water use say twice a week, and sometimes we are forced to cultivate a small portion of our farms. And sometimes it attracts conflicts among us, especially for people who are not patient. (Farmer interview, Themi, 20 May 2022)

In a group discussion it was also pointed out that:

> we cooperate to maintain the canal. For example, when there is a need to repair it or clean it, we normally organize ourselves and do the needed work. (Focus group discussion, Themi, 18 May 2022)

Farmers in Arusha did not actively bring up health considerations related to polluted water as an issue and when prompted farmers indicated that they considered it a normal risk. An agricultural officer indicated that farmers actively use the treated water released from the wastewater treatment plant. In recent years farmers have started using it for vegetable irrigation too, which is thought to pose considerable health risks to consumers (KII, Arusha, 24 May 2022). De Raat (2018) quotes an engineer from the treatment plant who emphasizes that it does not matter much whether farmers take water from above or below the plant's discharge into the stream, as the water is 'already quite polluted' anyway with human waste. The city's sewerage system only covers about 8% of the area with the rest making use of a variety of on-site systems, as analysed in detail by Abwe (2019). He further describes the huge gap between rules and regulations at the national and city level on the one hand and the actual practices of applying water at the community and farm levels on the other.

In Khulna all the interviewed farmers in the urban and peri-urban areas of the city practice indirect wastewater irrigation. Farmers have a longstanding experience in such indirect wastewater irrigation: on average they have been following this method of irrigation for more than 14 years. In each cropping season they irrigate their land several times using a small irrigation pump or a direct drain from the source. The major crop cultivated in the area is rice, next to different seasonal vegetables such as tomato, pumpkin, eggplant and spinach. Additionally, some farmers also produce corn, maize, sunflower and mustard in these fields. All the farmers reported that the produce is sold at local markets and consumed in the urban vicinity. Most of the Khulna farmers work as a tenant on lands that are awaiting transformation. Being able to work in these areas is an important source of income. Rapid urbanization has fastened the land-use transformation in urban as well as peri-urban areas of Khulna city. Thus, farmers fear that the agriculture activities will be pushed away from the current irrigated areas around the river (Farmer interview # 1, 4, 6, 10, 20). On average, farmers spend around BDT 4050 (€40) per season for irrigation, which mainly relates to fuel costs, rent for the pump, pipes and labour costs. Additional day labourers are employed during irrigation, which also creates employment opportunities for others. Almost all the farmers are willing to pay for higher-quality irrigation water. On average they are willing to pay around BDT 1500 (€15) per season for the irrigation water. Payment for better-quality water would create additional revenues for the water-supplying agency. However, the water quality should have a certain quality and should not be a financial burden for them, which was reflected during the FGDs:

> If the irrigation water is adequately treated and irrigation facilities are well developed for agricultural practices we will pay to the concerned authorities. However, we are poor people and we can't afford to stop agricultural practices. So, we could accept some cost sharing model within our affordable limit. (Focus group discussion #1, 2, 3, Khulna, 6 February 2022)

The majority of farmers in Khulna mentioned that they do not face any legal issues related to current IUA practices. Only a couple of farmers found the available quantity of irrigation water during dry periods a limiting factor for irrigation (Farmer interview # 2, 4). This could also be due to the location of the agricultural areas – close to water bodies – and therefore a good access to the irrigation sources.

Farmers in Khulna are aware of the presence of valuable nutrients in the water, but also reported the presence of worms, solid wastes, insects, bacteria and excessive growth of weed in the field reducing the yield (Haldar et al., 2022b, 2021; Mojid et al., 2010). The bad smell sometimes makes it difficult for the farmers to work with the current water source. Almost all the interviewed farmers reported health issues such as skin irritation, breathing issues, wounds on hands and legs, whereas some farmers could not immediately recognize any health issues related to the irrigation practices. These results align well with a recent study on peri-urban farmers practicing indirect wastewater irrigation without any protective equipment (Haldar et al., 2022b). Due to the health risks most of the farmers take precautions either by consulting local doctors or by relying on a long-standing experience with working with indirect wastewater irrigation.

As irrigation water in Khulna is high in salinity (Haldar et al., 2020), farmers need to apply additional fertilizer or soil moistener to neutralize the excess salinity in the field. Farmers would switch to rainwater harvesting if that would be possible, but they are aware of the poor reliability and availability of such an alternative source, especially during the dry period. The majority of the farmers do not think wastewater with current poor quality should be a source of irrigation in the longer term. However, they recognize the benefits of such sources as they are less costly, easily accessible to the adjacent fields, have nutritional value and offer a good alternative for freshwater sources that are hardly available in the surroundings (Farmer interview # 2, 5, 6, 10, 14). Thus, wastewater could play a crucial role in supplying necessary irrigation for urban agriculture if the quality can be improved and then further supplied to the farmers. In terms of water and occupational health risk management, farmers so far only rely on their own experience and on mutual collaboration.

Interlinkages with other urban practices

Current IUA practices in both Khulna and Arusha are embedded in a range of other informal practices related to sanitation and sludge management on the one hand and to marketing agricultural produce on the other.

Adjacent practices like septic tank faecal sludge emptying in Khulna are performed next to formal services of emptying sanitary pits and proper discharge and treatment processes, whereas manual emptying often ends up in the sludge being dumped in nearby drains and canals. As in the case of wastewater irrigation, authorities are aware of such practices but often do not take any legal actions considering the socioeconomic conditions of the marginalized waste managers.

Both the informal irrigation and sludge management practices could have legal consequences but are currently overlooked; hence, these practices shape and are being supported by service regimes around wastewater and sanitation management.

In Arusha a major part of the city lacks a functioning sewerage system and relies on pit latrines for sanitation. Both urban drains and natural streams flowing through the city collect and flush human waste, particularly during and after heavy rainfalls. At the lowest level, government actors and non-governmental organizations provide support to and interact with households and decentralized pit latrines' emptiers in a pragmatic way, condoning practices that higher-level institutions consider illegal. There are big differences within and between neighbourhoods, but in any case there are households without any sanitation facilities and households that practice 'flooding-out' as a method of pit emptying, meaning that they are opened with heavy rains and drain with the excess water. Such practices of emptying pit latrines during floods is also a common sight in Dar es Salaam (Tuju, 2015). The resulting contaminated waters from streams and rivers are then applied as irrigation water in urban agriculture without any treatment.

The IUA practices in both Khulna and Arusha are closely connected to the sale of agricultural produce on local urban markets. Except for private consumption, all rice and seasonal vegetables are sold in the local markets of Khulna. Selling products in local markets is more convenient for the farmers as it reduces costs of transport to bigger markets. Farmers in Arusha indicated that they mostly grow leafy vegetables as these have a stable and large daily demand by consumers. Farmers take their produce to Samunge market, which is considered a semi-wholesale market or farmers' market, from where the produce is distributed to smaller markets, shops, food stalls and street sellers. By using this market, farmers can sell their produce quickly in comparison to selling directly to consumers. They indicate that it reduces their time for marketing in favour of spending time on production.

Service regimes between sector regimes and irrigated agriculture practices

Despite being at tension with formal regulations on land and water use (farmers do not have land titles, are not organized in water user associations and lack water permits) urban farmers extensively utilize open spaces and riverbanks for irrigated rice and vegetable production. In both Khulna and Arusha, this is tolerated, if not facilitated and promoted, by both state and non-governmental development organizations. It signifies the service regimes as spaces for interaction between farmer's practices and water and agriculture sector regimes.

In Arusha, there are four organizations that take part in the governance of IUA at sector regime level: the Arusha Urban Water supply and Sanitation Authority (AUWSA) and three departments under the municipal council: the Urban Planning Department, the Health and Environment Department, and the Agricultural Department, which includes an irrigation section. The argument that irrigated urban agriculture has multiple benefits such as the clearing of unsafe bushy areas, provision of income for urban entrepreneurs and food for urban consumers is the basis for a somewhat positive attitude observed at these organizations, despite formal rules prohibiting many of these practices.

The Health and Environment Department intentionally issued policies on riverbank use and effluent irrigation only selectively and at a slow pace. AUWSA delivers partially treated wastewater to an officially recognized irrigation scheme. International development organizations, working with local state organizations, support irrigated urban agriculture in providing technical advice, improved seeds as well as training modules to enhance entrepreneurial skills. Urban agriculture is only enforced when domestic and agricultural interests interfere with regard to land use plans or health (contamination) and environmental (river bank erosion) concerns (Thomas et al., 2021a, 2021b). Meanwhile, there seems to be an overall consensus within the local government authorities that interference in the livelihood practices of this vulnerable group is deemed unwanted as long as no disturbance to the surroundings takes place. De Raat (2018) also described how farmers mobilize elected local government officials to ease the implementation and enforcement of rules to avoid negative impacts on the irrigation practices. One of the interviewees points out:

> Who is going to identify the wrongness of urban agriculture? If no one reports a case of disturbance to the ward office, urban agriculture will continue irrespective of that it means encroachment of urban [designated] areas. (KII, 1 February 2022)

Officials in both cities seem to be aware of untreated discharge of wastewater and subsequent (indirect) use of wastewater for agricultural activities. They think such practice should not be encouraged as there are health and environmental concerns. However, they also acknowledge the importance of these practices for livelihood incomes and are aware of water scarcity affecting the region and the necessity of wastewater treatment to improve surface water quality. With this, they legitimize not only the current practices of wastewater use in irrigated agriculture, but also the emergence of a service regime that is constituted by and supporting such practices.

The Khulna authorities emphasize that there is no specific cell or entity to monitor the practice. Khulna Water Supply and Sewerage Authority is the responsible authority for the treatment of wastewater whereas the Department of Environment has the power to impose fines for damaging the environment. However, in reality such actions are not taken either due to lack of personnel or expertise in the relevant issue or due to lack of alternative irrigation sources, which is reflected in the following statement:

> In the peri-urban area of Khulna city, we know that there is the practice of wastewater irrigation. We know that peri-urban farmers face water scarcity for irrigation and it is indeed growing day by day. Thus, dependence on wastewater irrigation is also increasing. In my opinion, wastewater should not be used directly in crop fields. Urban wastewater should be used in irrigation once it is treated. (KII, Khulna, 28 February 2022)

Current rules and regulations in Khulna lack a clear explanation on the restrictions or suitability of urban water in agriculture. However, the recently formulated Bangladesh Delta Plan 2100 (Government of the People's Republic of Bangladesh, 2018) encourages the use of alternative irrigation sources (rainwater harvesting, wastewater reuse) in a safe way. Lack of coordination and collaboration among different organizations was pointed out as a major obstacle for formulating a plan for safe reuse of urban water in agriculture.

In sum, the existence of practices of IUA in both cities cannot be explained by just the lack of rule enforcement by health and water departments. Instead, there are service

regimes in place, characterized by the continuous interaction between farmers, state and development organizations, materials and (informal) rule sets, which lead to tolerance and even facilitiation of IUA practices despite the local formal regulations on land and water use. Temporary commitments and rules enable the urban irrigation practices in Khulna and Arusha, while tolerating non-compliance to the formal rules, and ignoring the health risks for farmers and consumers.

Discussion

This paper looked at the lack of understanding of a gap between, on the one hand, rule enforcement in sector regimes of urban agriculture and urban water and, on the other hand, practices of IUA that are de-facto tolerated or even facilitated. To investigate this gap we applied a new approach based on a multidisciplinary understanding of *service regimes* that can be situated between urban sector regimes of Agriculture and Water and local practices of irrigated urban agriculture. We investigated the actual practices of IUA in informal urban settlements and open urban spaces in Khulna (Bangladesh) and Arusha (Tanzania).

The results of our findings on IUA in the two secondary cities have shown that, for one, there are significant differences in how and by whom irrigation *practices* are performed. In Arusha, wastewater and river water is used in the cultivation of leafy vegetables for the local urban market, whereas in Khulna irrigation is practised in mainly rice production next to some seasonal crops.

The encountered *service regimes* in both cities differ in terms of specific local actors involved, types of crops produced, plot sizes, water qualities applied, negotiated irrigation schemes among farmers, and awareness of health risks among practitioners.

The *sector regimes* of urban water management and urban agriculture are, however, comparable in both cities, with separate local departments for water and agriculture and their respective rules and regulations about water and food safety that are poorly enforced.

Second, it is important to address and understand IUA practices as connected to other everyday occupational and domestic practices. Especially in the non-regulated settings of IUA as described above, the boundaries between everyday domestic and working practices and between urban systems which provide the resources and services (drains, water pipes, sewers, nutrients, energy) are indistinct. This is important, as any measures that will be taken to enhance IUA, or those reducing the health risks of workers or stimulating the marketing of local vegetables, will have severe implications for adjacent practices. We singled out the practices of 'marketing agricultural produce' and 'sanitation practices' as mostly connected to the practices of irrigated urban agriculture. This conglomerate of practices is interconnected via its three elements (Shove et al., 2012, p. 24): its materials (water, nutrients, soils and crops), its competences (growing and selling of crops, draining and irrigating) and its meanings (ideas of how to make a living, dealing with health risks, hygienic norms).

Third, considering such conglomerates of adjacent practices means that the scope of analysis of IUA needs to cover a wider range of urban activities than agricultural practices alone. Urban water produced in industries and housing estates and transported through main urban sewers and drains eventually form the source for

irrigating and fertilizing of mostly scattered and non-regulated urban agriculture fields. Their products will end up at public marketplaces where food safety monitoring is mostly lacking.

Fourth and lastly, in such overlapping scenes of practices and service provision, only focusing on the workings and regulations of sector regimes like 'water' or 'agriculture' or 'urban planning' in Arusha and Khulna would be insufficient to reveal the challenges encountered by practitioners on the ground. The middle ground of 'service regimes' – formed around specific practices combining technologies, user routines, and organizational forms of service provision – seems more suitable to describe and analyse the handlings of practitioners working in IUA including sludge management, irrigation and marketing.

Overall, the paper offers a multilevel insight in how IUA is being practiced, facilitated and enforced in secondary cities in the Global South. Irrigation and cultivation practices are connected to practices of sanitation (materials, meanings and handlings of wastewater and drainage water) and food marketing (selling produce on local markets). Such bundles of practices together comprise the service regimes at work for irrigated urban agriculture in both cities, despite the formal sector regimes of urban water and agriculture in place. This paper may hence provide the material to start rethinking current local urban policy arrangements that are based on strict sectoral divisions between water, agriculture and food and designing arrangements that take into account the interlinkages between practices of urban cultivation with practices typical for the urban economies in the Global South: street selling and purchasing of food and managing sanitation and drainage with or without having access to formal infrastructures, rules and resources.

Conclusion

Urban and peri-urban agriculture plays a pivotal role in sustaining livelihoods for farmers and contributes to the overall food security of cities of the Global South. In this paper, the study of two different cases of irrigated urban agriculture in the (peri-)urban spaces of secondary cities in Tanzania and Bangladesh indicates that even though the agricultural and geographical settings are different, similarities prevail. The differences are in the crops cultivated, their sites, connections and means to apply irrigation water and types of farmers. Yet, in both cities the ways of cultivation contribute significantly to livelihoods of farmers and city dwellers despite health risks and risks of harassment and displacement. The risks of irrigation with polluted waters are mostly known to its practitioners and to authorities, but this practise is consciously overlooked by the authorities unless severe negative impacts are reported.

Irrigated urban agriculture practices in both cities are connected to adjacent practices of wastewater handling and sanitation as well as of food safety, via its material elements of infrastructures and nutrients, the various competences of farming and marketing and its social and cultural meanings. These bundles of practices and the ways they are governed, supported and sustained comprise the locally specific service regimes, situated on the level between sector regimes of agriculture and urban water and practices around irrigated urban agriculture.

Overall, irrigated urban agriculture is a crucial activity for urban farmers and consumers in the Global South to sustain livelihoods, which would first need careful

recognition and encompassing integrative policy arrangements for creating safe and circular urban food systems. The implications of adopting insights on service regimes for the governance of irrigated urban agriculture in the Global South are manyfold, but would at least mean to resolve the institutional boundaries between urban water and agricultural sector regimes and the understanding of the interrelations of measures in each of these sectors to food safety, public health and sanitation.

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