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WATER, FOOD, AND IRRIGATION

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Introduction: Water and Food

This chapter explores the key role that irrigation plays in food production worldwide and points out the important challenges that this sector faces from a socio-environmental justice perspective. Water and food are intrinsically related. Water stands at the basis of all plant growth and as such forms the basis of all food production on earth. Agriculture also provides other needs of present-day society, such as raw material for clothes, building materials, fuel, flowers, medicine and many more. Broadly, there are two agricultural production modalities based on where the water used for crop growth comes from. These are rainfed and irrigated agriculture. Rainfed agriculture depends, as its name implies, solely on direct rainfall, while irrigated agriculture depends on water that is administered to the crops by humans through the use of hydraulic infrastructure such as buckets, weirs, canals, dams, tubes, and pumps amongst others. Irrigation water often complements rainfall, but in some cases, agricultural production solely depends on irrigation water that comes from surface or groundwater, or both. This process where people, nature and technology intertwine and co-shape each other forms the basis for food production and related livelihoods.

The continued expansion and intensification of irrigated as well as rainfed agriculture is often advocated as the only way to move forward in producing enough food, fibre, and other agricultural products for the growing world population and its demands. So far production has kept a-pace: "while the population has risen from 3 billion in 1960 to 7.5 billion in 2017 (and is expected to reach 9.2 billion by 2050), the proportion living near starvation conditions fell from between 25% and 30% in 1960 to just over 10% today" (Robinson, 2018: 140). Most undernourishment and near starvation comes from situations of violent conflict, state failure and the extremely uneven distribution of wealth worldwide, not because there is a lack of food at the global level.

Currently the highest rise in the demand for agricultural products does not come from population growth itself, but from more luxurious diets of the world's middle and upper classes (Borras & Franco, 2012; van der Ploeg, 2014), who have a higher per capita consumption of fish, meat, eggs and dairy as well as other often imported luxury food products such as fresh fruits and vegetables. All of these products require more water and land per produced calory than staple and traditional foods. Currently, livestock production alone uses 70% of the world's agricultural land (Robinson et al., 2011). Ironically, food abundance in many societies has become one of the most

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important public health risks through widespread obesity, and millions of tons of produced food are thrown away yearly. At the same time, problems related to poverty, malnutrition, social exclusion, and related disparities in resource distribution in rural societies, particularly in the Global South prevail. The environmental costs of increased food production are also high and include soil degradation, water pollution, aquifer depletion, destruction of the world's major biomes, reduction of biodiversity, and increased greenhouse gas emissions from agriculture (Martinez-Alier, 2009).

Within this context, and placing irrigated agriculture within the broader context of food regime analysis (Holt-Gimenez & Shattuck, 2011), in this chapter we first present the development of the irrigation sector in the last century. Secondly, we explore the main challenges this sector is currently facing from a socio-environmental justice perspective. Finally, we present how peasant/smallholder production systems fit in this context and show some promising irrigation-based grassroots initiatives of smallholder producers that contribute to more sustainable food networks. The chapter closes with the conclusions.

Placing Irrigation in Global Food Production

Rainfed agriculture currently occupies between 75% and 80% of global arable land and produces around 60% of total agricultural production (Molden, 2007; see also FAO, 2020). Rainfed agriculture is prone to seasonal climatological variations that negatively affects crop production. This effect is expected to increase in the future due to global climate change (Ray et al., 2019). This makes production from rainfed agriculture in many areas of the world increasingly uncertain due to climatological extremes induced crop yield reductions and crop failure (FAO, 2020).

To overcome the uncertainties of rainfed agriculture, lengthen the growing season and enable multiple cropping seasons per year, for millennia people have diverted water from springs, streams, rivers, lakes and wells to irrigate their crops. Irrigation leads to higher and more secure agricultural production, while also enabling production in areas and in seasons in which these would normally not grow under rainfed conditions. As such irrigation has for centuries played a key role in food production and security of many societies around the world. As the basis for food production, irrigation has also played a key role in the cultural, political and economic structures of many societies.

Today many rural societies depend on irrigation for agricultural production for self-consumption and the market. Around 20–25% of the global agricultural area is irrigated, accounting for over 40% of total crop production; a value that is much higher when taking into account the economic value of irrigated production (Molden, 2007; FAO, 2020). According to Thenkabail et al. (2009) at the end of the last millennium worldwide there were around 300 million hectares (Mha) irrigated. This was comprised of 252 Mha from seasonal crops and 41 Mha from continuous year-round crops. According to these same authors, Asia accounts for 79% of all irrigated areas, followed by Europe (7%) and North America (7%). According to Faurès, Hoogeveen, and Bruinsma et al. (2021) irrigation expansion will continue as developing countries are expected to expand their irrigated areas from 202 Mha at the beginning of the 2000s to 242 Mha by 2030.

Irrigation Expansion in the Last Century: Controlling Waters to Feed the World

Since the 1950s, the irrigated area worldwide has grown exponentially. This was the result of enormous international and national investments to construct irrigation infrastructure and institutions to operate and manage them. The development of irrigation systems became an important means to develop rural areas, increase production, fight hunger, provide countries with food sovereignty and bring about capital accumulation and related socio-economic development (Molle, Mollinga, & Wester, 2009; Molle & Wester, 2009). Irrigation expansion took place on a three-pronged path which consisted of the development of large scale public irrigation schemes, investments in the expansion and modernization of smaller farmer-managed irrigation schemes, and the development of intensive groundwater use for agriculture as is explored below.

Large-Scale Public Irrigation Schemes

Surface water development has implied the construction of large scale infrastructure (dams, weirs, and canals) in most of the world's rivers to control and divert its waters to fertile lands aimed at the production of agricultural products. To this end a centralized bureaucracy specialized in the construction and management of these irrigation schemes was established in most countries (Molle et al., 2009). These powerful bureaucracies operated in a centralized top-down manner and in many areas forcefully created a new peasantry that was composed by a mix of local and re-settled families that were supported by state agencies to increase the production of specific crops (often staple foods), sometimes under strict state guidance and control (Veldwisch et al., 2012). The heavy financial burden that these bureaucracies held on national budgets coupled to the often poor performance of irrigation systems led to the decentralization of irrigation system management to organized water users associations around the world from the 1980s onwards (Veldwisch, 2013; Suhardiman et al., 2014; Hoogesteger et al., 2017; Cambaza, Hoogesteger, & Veldwisch, 2020). The results this decentralization had on the performance of irrigation management and production are variable (Senanayake, Mukherji, & Giordano, 2015) as they depended on context specific dynamics and outcomes (Suhardiman et al., 2014). One noticeable outcome of this process has been the increased control of large commercial farmers on irrigation management especially as many peasants/smallholders went bankrupt, sold their irrigated land and became labourers because they could not compete and remain productive in contexts of agricultural liberalization and globalization.

Farmer-Managed Irrigation Schemes

Private and collectively (farmer) managed irrigation systems play a key role in agricultural production worldwide. These decentred systems, that are often not recognized as irrigated area by state agencies and official data, existed in many regions of the world well before the larger-public irrigation systems. They are operated and maintained by farmers/users either privately or collectively through locally specific management forms (Boelens & Vos, 2014). External investments by state or non-governmental organizations, especially since the 1950s have often been used to expand and/or modernize these systems. However, these external interventions have in most cases also been accompanied by new technical, operational and management challenges (García-Mollá et al., 2020). Despite these challenges, these systems have shown great resilience to change as smallholders continue to sustain these systems (Hoogesteger et al., 2023a) as part of their peasant livelihoods as is further explored below.

Groundwater Irrigation

Groundwater irrigation took flight especially since the 1970s in many countries, due to advances in drilling technology and sharp drops in the cost of – often subsidized – pumps and the fuel or electricity to run them (Hoogesteger & Wester, 2015). Under these conditions, and paraphrasing

Shah et al. (2007: 409), groundwater became *available on site,* providing farmers with on-demand, just-in-time water for a very large variety of crops. This development was atomistic meaning that thousands and in some cases millions of farmers individually dug and controlled their own wells covering significant area extensions and bringing with it increased crop production, food security, poverty reduction and economic development to many rural families and societies (Hoogesteger, 2022). This has led to intensive (unsustainable) groundwater use and related aquifer overdraft in many parts of the world including India, the Western USA, the North China Plain, Spain, Iran, the Middle East and Northern Africa, the Peruvian and Chilean coast, and Mexico amongst others (de Graaf et al., 2019) with sever socio-environmental impacts as is further elaborated below.

Irrigation-Related Challenges

Though irrigated agriculture plays a central role in sustaining the food production levels world-wide, it is a sector that is also fraught with important challenges. Here we concentrate on two of the multiple domains of challenges and frictions: challenges within the irrigation systems, and environmental effects.

Challenges within Irrigation Systems

Many irrigation systems were built with public, private or donor investments and require high operational costs. In many irrigation systems, especially in the developing world, state agencies, and/or collectively managed water users associations are financially constrained and have managerial challenges resulting in prolonged break-downs, water delivery problems, low performance, and reduced cropped areas. In many systems the solution to managerial and water related challenges is sought through the modernization of irrigation infrastructure (new gates, lining canals, pressurizing irrigation, installation of sprinkler and drip, etc.). This is often seen as the silver bullet to increase water use efficiency and through it release water for new irrigated areas, other sectors or nature (Venot, Kuper, & Zwarteveen, 2017). However, this drive and blind belief in technology often oversees more simple, cost-efficient and effective measures to overcome the challenges of irrigation systems. In addition, "modernized" farmers tend to use "water savings" for the expansion of irrigation (Vos & Boelens, 2014). Through such modernization projects larger and often more capitalized and politically powerful producers tend to acquire more secure access to large shares of irrigation water than small producers (Franco, Mehta, & Veldwisch, 2013; Dell'Angelo, Rulli, & D'Odorico, 2018). This affects in particular peasant, indigenous and women farmer groups in irrigation systems.

In areas of intensive groundwater use, groundwater management and control by state agents, water users associations or through co-management arrangements has proven extremely challenging (Molle & Closas, 2020a; 2020b). The result is a race to the bottom of the aquifers in which economically powerful pumpers (commercial farmers, cities, industry and mining) outcompete smallholders that are not able to invest in the deepening and repositioning of wells or pay the ever-increasing pumping costs. The result is a silent process of water grabbing and accumulation in which smallholders and peasant producers gradually lose their access to groundwater and related livelihoods (Hoogesteger & Wester, 2015; Hoogesteger, 2018).

These "internal" challenges are exacerbated by external challenges related to water availability which is threatened by increased climatic variability related to global climate change and inter-sectoral competition. In many areas of the world great pressure is exerted on irrigation to liberate water (in particular from peasant land) for other water uses such as urban/domestic and industrial

(Molle et al., 2010). As Molle and Berkoff (2009) show, the financial and political clout of these sectors often leads to hidden and outright transfers of water from (peasant) irrigated agriculture to these more powerful sectors.

Broader Environmental Effects

The large infrastructure that is constructed in rivers to control and divert water for use in irrigation systems has drastically changed river environments, lakes and related water flows (Boelens et al., 2022). This affects – and in many cases severely destroyed – river, lake, and estuary fisheries and related ecosystems as well as the livelihoods and riverine cultures that depend upon them (e.g., Shah et al., 2019; Flaminio, 2021).

In many irrigated areas of the world salinization caused by a lack of appropriate drainage and increasing pollutants from pesticide and fertilizer residues in irrigation water have made millions of hectares of land unsuitable for agriculture (Ritzema et al., 2008). Salinization is often closely related to water quality deterioration. As rivers and thus irrigation water become increasingly polluted worldwide due to industrial, urban and agricultural pollutants (Strokal et al., 2019), new challenges arise for the production of healthy food crops and the sustenance of fertile soils.

In areas of intensive groundwater use, aquifer overdraft has become a serious socio-environmental threat. This affects the geo-hydrology and the contribution of aquifers to river flows (de Graaf et al., 2019) and related environments such as wetlands. Groundwater declines can also lead to salinity intrusion in coastal aquifers and land subsidence is a common occurrence in areas of intensive groundwater use. While the former has rendered some coastal aquifers too saline for use, land subsidence can lead to breaks in underground pipelines (sewerage, oil, gas, etc.), damages to houses and infrastructure and increased risk of flooding. Over-pumping can also have very serious impacts on groundwater quality. As aquifer levels decline, concentrations of arsenic, fluor and other toxic elements (nitrates, sulphates, heavy metals, etc.) increase in several aquifers leading to toxic concentrations of these elements in extracted groundwater (Knappett et al., 2020). All of these environmental changes tend to hit rural communities and smallholder farmers the hardest.

Within this broad context and generalized trends, there are very large differences in terms of how irrigated agricultural production is organized and who reaps its benefits or carries it's socio-environmental burdens. This is further explored in the next section.

Irrigation, Globalization, and the Expansion of Productivist Agriculture

Food trade is maybe as old as civilization but it has gained increased importance especially since the process of rapid globalization took flight in the 1980s. This entailed the liberalization of markets in most countries around the globe, the development of faster and more efficient food transport systems and the rise of transnational food chains and enterprises. The increased trade of agricultural goods has gone hand in hand with an increase in virtual water exports (that is, the water that is needed to produce the goods that are traded) mostly from the global south to the global north (Dalin et al., 2012).

Globalization and increased virtual water trade is closely associated with the rise of so-called productivist agriculture, characterized by an increased and increasing number of larger, well-capitalized (corporate) farms. These farming operations tend to access and accumulate the most fertile and productive lands and water for irrigation. Though a very broad spectrum of farming styles prevails the gap between productivist agriculture and smaller family/peasant-run farms is steadily increasing. This product of globalization is usually characterized by intensification, concentration, and specialization for which irrigation is often needed (Robinson, 2014, pp. 62–64). In the process capital often replaces labour as the production process transforms towards an increased reliance on new technologies, external specialized commodified inputs, mechanization, automation of production processes, and the application of advances in biotechnology.

Intensive use of technologies for production of high value crops such as vegetables, fruits, and flowers is done above all in irrigated agriculture and has gone hand in hand with a tendency of individual farms to specialize in the large-scale production of standardized outputs that can be easily processed and shipped to markets, both locally and worldwide. Specialization does not only take place at farm level but also at regional level. As a result, global hotspots of production and export of specific irrigated crops have emerged. These source a large portion of the world demand for one specific product from one or a few relatively small regions in the world. Examples are the production of roses and cut flowers in northern Ecuador, Colombia, Kenya and Tanzania; asparagus in the Ica Valley of Peru and central Mexico; grapes and other fruits in coastal Peru, Chile and South Africa; blackberries and avocados in western Mexico; fresh-cut vegetables for northern Europe in Murcia, Spain; pistachios in the province of Kerman, Iran and almonds in California, just to name a few examples in which production is irrigation based.

This specialization often goes hand in hand with the concentration of the means of production in fewer hands leading to less but larger specialized farming units that increasingly set of their production (sales) through food processing industries, many of which operate in global markets. These sales are often arranged through contract farming in which agricultural production is carried out via an agreement between the buyer (wholesaler, processor, and retailer) and the producer. It has also promoted the transformation of farm produce into inputs for the wider global food packaging, transport and manufacturing system. As a result producers and end-consumers of food have become increasingly removed from each other.

Many critical scholars have pointed out that the development of such specialized, large scale corporate agriculture underlies ongoing processes of land and water grabbing and accumulation by local elites and transnational agricultural companies in Africa, Asia and South America (Borras & Franco, 2012; Mehta, Veldwisch, & Franco, 2012). These processes of land and water accumulation often go hand in hand with the dispossession of access to these resources by peasant families and the transformation of rural livelihoods through increased proletarianization to poorly paid agricultural labour in productivist agriculture (Hoogesteger & Massink, 2021) and migration (Mena-Vásconez, Boelens, & Vos, 2016). These processes are compounded by outright and blatant dispossession through the use of force, but also through a slower process of de-peasantization which includes roping in small farmers into corporate modes of production through for instance contract farming schemes (Veldwisch, 2013; Hartman et al., 2022). These developments threaten the peasantry and the important role that it plays in local food production as is further explored below.

Peasant Production in Regional Food Systems

It is widely acknowledged that peasants see their household as a production unit that is strongly related to its own consumption and other needs, rather than by the capital profit maximization logic that dominates in commercial agriculture. This means that resources, labour and production do not only have an exchange value but also have a very important use value (van der Ploeg, 2014). The often-made distinction between "domestic/household" and "productive activities" generally blurs, as they combine and overlap. As a result, households are organized and sustained through a wide diversity of activities both within as well as outside of the production unit. In this sense, peasant households and communities are highly dynamic and integrated into the larger regional, national and transnational economies through their insertion in diverse labour markets, globalized production, trade and cyclical, or permanent migration (and related remittances) of household members (Veldwisch & Spoor, 2008; Hoogesteger & Rivara, 2021).

Peasant production, most of which combines irrigated and rainfed agriculture with extensive animal grazing as part of diversified production strategies, tends to focus on the cultivation of food crops for self-consumption and sale on local or regional food markets, though important exceptions exist (Hoogesteger & Rivara, 2021). It plays a key role in catering the regional and national food needs in many developing countries where corporate food companies, supermarkets and processed food are less dominant in the food sector. In many regions irrigated peasant production plays a fundamental role in the production of fresh vegetables, fruits and dairy products for the rural and growing urban populations.

Though in many areas of the world a process of gradual social differentiation and related de-peasantization (where less and less peasants remain in production) has been identified (Bernstein et al., 2018), renewed efforts to reproduce and re-peasantize food production through sustained or increased smallholder-based production exist (van der Ploeg, 2014). Some interesting processes in which smallholder/peasant production has increased or been re-vitalized based on irrigation are explored below.

Farmer-Led Irrigation Development

Farmers have been developing irrigation for centuries, largely without external support. Recently research has shown that smallholder farmers have continued expanding the irrigated area across a variety of agro-ecological contexts and tapping into different types of water resources, especially in Sub-Saharan Africa (Woodhouse et al., 2017). This process of relatively recent expansion of irrigation is called farmer-led irrigation development and has been defined as "a process whereby farmers drive the establishment, improvement, and/or expansion of irrigated agriculture, often in interaction with other actors (government agencies, NGOs, etc)" (Veldwisch et al., 2019: 2). Despite its substantial contribution to agricultural production and the expansion of irrigation over large areas (Bossenbroek, Van der Ploeg, & Zwarteveen, 2015; Hamamouche et al., 2018; Hartman et al., 2021), the process has remained little recognized by state and development organizations. These irrigating farmers largely grow for the nearby market, and have intensified their production processes, exemplified by the use of improved seeds, pesticides and fertilizers, by the degree of mechanization and by the hiring of labour (de Bont & Veldwisch, 2020).

Irrigated (Peri)Urban Agriculture

Irrigated agricultural production has been stable or growing in and around many cities in the global South (Drechsel & Keraita, 2014). This is mostly practiced by poor city dwellers, who frequently use urban water flows containing waste water, either treated, diluted or raw (Crush, Hovorka, & Tevera, 2011). Regardless of health risk for both farmers and consumers substantial areas are irrigated in this way.

Most countries have approaches to urban irrigation that aim to enforce strict standards and rules regarding the use of urban space and urban water sources. These policies are often combined with promulgating high-tech sanitation and water treatment solutions. This approach that combines an emphasis on rule-enforcement with faith in technological solutions has largely failed, with untreated and partially treated wastewater mixing with natural flows and continue to be used as a stable, year-round, flow of water that by default re-cycles nutrients. Ghana forms an exception and has taken up a more expedient approach that is very promising (Ayambire et al., 2019).

Agro-ecology and Local Organic Solidarity and Production Networks

Around the world, over the last 20 years there has been a resurgence of local (mostly organic) farmers markets and producers cooperatives. In these, smallholder producers sell their products directly to the cooperative or the end consumers without intermediaries. This enables producers to make higher revenues from production while bringing consumers local fresh produce (Hoogesteger et al., 2023b). Most of these local markets depend on, and are the result of, extended solidarity networks that are often historically initiated by peasant communities and federations, sometimes supported and facilitated by non-governmental organizations and local governments. Most members of these networks produce organically or follow principles of agro-ecology and permaculture. This type of agriculture is based on the enforcement of agrobiodiversity, zero agrochemical usage (pesticides, industrialized fertilizers, etc.), empowerment of solidarity networks (Vos et al., 2020), and enhancement of socio-ecological resilience capacity of production systems (Wezel et al., 2009).

Conclusions: Are We Feeding the World in a Socio-environmentally Sustainable Manner?

Over the past century worldwide food production has kept a-pace with population growth, ensuring widespread food security and enabling a transition to richer and more luxurious diets for many around the globe. Irrigation has played a key role in this process, but from a socio-environmental justice perspective important questions can be raised about its socio-environmental costs and current processes. The construction of irrigation infrastructure in most rivers of the world has destroyed river dependent ecosystems and related livelihoods. Intensive groundwater use has led to the dissection of river base flows and wetlands as aquifers are over-exploited and groundwater quality deteriorates in many areas of the world.

Socially the development of surface and groundwater irrigation initially brought food security and economic development to many rural areas, forming the basis for the development of new-peasantries and smallholder based rural development. Especially since the late 1970s liberalization, globalization and commodification of production through (inter)national food chains has increasingly threatened peasant irrigation and related livelihoods. The rise and expansion of productivist agriculture at the expanse of peasant agriculture is leading to fewer, specialized larger production units that focus on economically lucrative agro-export crops such as flowers, fruits, vegetables, or dairy. These productive units accumulate access to land and water resources through legal and illegal mechanisms of resource grabbing often at the cost of peasants' access to these resources. The result is increased resource and capital accumulation in the hands of a small elite, while rural livelihoods increasingly come to depend on migration and proletarianization. This process of de-peasantization, which is facilitated in many countries by liberal agricultural, land and water policies, is troubling from a socio-environmental justice perspective in terms of resource access equity and when recognizing the important role that peasant agriculture plays in local and regional food supply and food security systems.

The promising developments of farmer-led irrigation development in Africa, peri-urban agriculture based food production and local agro-ecological and organic production networks in many parts of the world offer promising, more sustainable and socially equitable, alternatives to the productivist imperative in the irrigation sector. Although these initiatives are generally not recognized nor supported by governmental policies, they show that more sustainable, equal and just food production systems that build on peasant and smallholders agriculture are viable in different contexts. Therefore, global discussions on water and food, irrigated agriculture and socio-environmental sustainability need to incorporate peasant agriculture as a key building block for the (re)shaping of global food regimes. For policy makers there is much scope to recognize, support, and upscale such grassroots initiatives. Finally, we as consumers can decide what kind of agriculture and producers we want to support through our choices about where and what foods we buy and consume on a daily basis.

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