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'In These Complicated Times': An Environmental History of Irrigated Agriculture in Post-Communist Ukraine

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ABSTRACT: This paper examines irrigation in post-communist Southern Ukraine, mapping the continuity of late Soviet investments in centre pivot irrigation technology in the post-Soviet period, but also situating this large-scale irrigation in a regional context where there are significant, but uneven, changes in water access. Framing irrigation change within long-term environmental history, this paper argues that post-Soviet developments are the consequence of a collapsing modernisation project. An Actor Network approach is used to explore the ontological politics surrounding possible alternative uses of irrigated farm fields, as well as the 'agency' of centre pivot irrigation technology, which 'acts' to undermine landowners' rights. This is noted as ironic, because the technology was originally imported from the United States during the Cold War, while post-communist land reform was influenced by the Washington Consensus. Uneven water access near the area with centre pivot irrigation is explored. Understanding this uneven geography puts post-Soviet agrarian change in Ukraine in perspective, identifying the disappearance of collective farms as a factor driving changing water access. The paper concludes that 20th century Soviet investments in irrigation are potentially more sustainable than comparable investments in other countries – as in the American West – complicating the conventionally negative view of Soviet environmental management.

KEYWORDS: Irrigation, agrarian change, environmental history, Ukraine, USSR

INTRODUCTION

Following WWII, the Soviet Union pursued agricultural intensification and land improvement to boost agricultural production. This resulted in the construction of extensive irrigation works in Central Asia, the Caucasus, southern Russia, and – important for this paper – Southern Ukraine. They were designed and operated in relation to a specific set of conditions that no longer prevail, and, since the Soviet collapse, questions have arisen concerning their sustainability, governance, and adaptability. For example, irrigated agriculture was designed for quite large-scale farm units (collective farms) and was situated in a rigid and authoritarian centralised planning system. Based on the overall goal of ensuring national food security, the cost of inputs/factors, including for water, were heavily distorted in favour of producers. In Ukraine, post-communist land and economic reforms led to the privatisation of land, the almost complete disappearance of collective farms, the removal of price distortions, and a policy emphasis, relatively speaking, on free trade (in lieu of agricultural policies promoting national food security). Moreover, as we shall see below, the privatisation and parcelisation of Ukraine's large farm fields did not take into account the specificities and needs of large-scale irrigated agriculture, eventually leading to conflicts. Finally, the economic crisis following the Soviet collapse made it difficult to finance maintenance of irrigation systems, many of which fell into disrepair. It also led to a drop in demand for irrigation as land users lacked the means to irrigate. There are broad similarities to the causes of post-Soviet irrigation collapse in the different former Soviet republics, though of course with important specificities for each country. Western donors jumped into this breach, promoting governance reforms – usually in the form of water user associations (Hellegers, 2005; Sehring, 2009). While discussion

generally concerns technical and institutional solutions, lurking in the background is a persistent view of a 'dark legacy' (Kenarov, 2015) of Soviet inefficiency and mismanagement in relation to irrigation (Spoor and Arsel, 2010), and more generally in relation to agriculture (Libert, 1995) and the environment (Goldman, 1972).

While this reputation is partly deserved, this paper presents a case where Soviet investment in irrigation in Southern Ukraine (see Figure 1) has adapted to market circumstances under relatively unreformed water governance, with environmental consequences that are dire in some places and for some groups but overall are not catastrophic. The focus is on Soviet-era investments in centre pivot irrigation, and on nearby areas with different forms of irrigation. There has been change, and this will be detailed, but there has also been surprising continuity, shaped by technology. As such, this case complicates conventional narratives about post-Soviet agrarian change. Tracing and mapping 'continuity and change' is the main purpose of this paper. I also seek to challenge conventional 'Western' ideas about the differences between collective farming and Western farming systems. A better understanding of the similarities and differences within a long-term perspective, I argue, aids in comprehending the real effect of land and economic reforms on post-Soviet agriculture, and the overall sustainability of irrigated agriculture in Southern Ukraine.

Figure 1. The main area for centre pivot irrigation in mainland Southern Ukraine.



This paper is informed by established theories – the social construction of technology theory (SCOT) and Actor-Network Theory (ANT) – whose application to post-socialism is still an emerging field (Richardson, 2016; Visser, 2016). According to these approaches, objects – technology or non-human 'nature' – have agency (Latour, 2007) and politics (Winner, 1980), shaping and constraining the agency of humans entangled with this technology. Framing the question less abstractly: to what degree is

irrigation design and technology from one regime, operating under a certain set of assumptions, adequate for a different regime with different assumptions (Mollinga, 2010).

This paper is organised as follows. I first frame post-Soviet agrarian change within longer-term Soviet and global environmental history, arguing that this generates relevant insights. I then discuss the theoretical implications of the agency of irrigation technology and of the fields themselves – conceptualised as 'management scripts' and describe the sources and approach for mapping and tracing irrigation. The history of irrigation in the region takes the reader to the point where, directly after post-Soviet land reform, the irrigation system teetered on the brink of total collapse. An empirical overview of the state of large-scale centre pivot irrigation today is then provided, while following sections describe various 'battles' for irrigated fields that help to explain both how some irrigation disappeared, and who has access to irrigation today. A last section, partially relying on previous research conducted by the author (Kuns, 2017) situates centre pivot irrigation in its varied regional context, before the conclusion.

POST-SOVIET IRRIGATION IN THE CONTEXT OF ENVIRONMENTAL HISTORY

While agriculture in the Soviet Union and the Russian Empire has been studied from the perspective of environmental history (Libert, 1995; Moon, 2013, 2016), it is still relatively rare to investigate post-Soviet farm restructuring and land reform from this standpoint, with some notable exceptions (Ioffe and Nefedova, 1998; Ioffe et al., 2006). This is an important gap to fill because a broad environmental historical frame can provide important insights into the question of recent agrarian change.

Environmental historians of the Soviet era traditionally focused on Promethean tendencies in environmental management and ideology, and the attendant disasters, i.e. the Soviet belief that communist ideology and centralised planning would prevail over all environmental challenges (Goldman, 1972), and the way in which this belief justified extensive 'geo-engineering' (Josephson, 2016), which led to ecological catastrophes including Chernobyl and the drastic shrinking of the Aral Sea. In this approach, the consequences of Soviet irrigation in Central Asia are among the most prominent examples cited. However, more recent work (with less of a focus on irrigation), emphasises the more nuanced, technocratic environmental management approach that emerged after Stalin, which "recognised local variation and experimental results" (Brain, 2010); struggled to adapt agriculture to local environments (Smith, 2014); more readily aligns with pre-Soviet thinking on how to overcome environmental challenges in the region (Weiner, 2000; Moon, 2016); and, concerning Central Asian irrigation, is more willing to acknowledge some positive aspects of Soviet water governance (Spoor and Arsel, 2010).

This nuanced view finds additional support in arguments stressing the similarities of Communist and Western environmental management (Molle et al., 2009) especially with respect to agriculture (Scott, 1999). Scott's famous arguments are especially important in this regard: that both collective-farm agriculture and Western industrial agriculture represent a 'high modernist' productivist style of agriculture which relies on science and technology to boost production volumes, and which redesigns rural landscapes so that they are more 'legible', enabling a more efficient exploitation of nature. Beyond shared ideology, there was also shared agricultural equipment and practices between East and West (Dalrymple, 1966; Bailes, 1981; Fitzgerald, 1996). Both modernist approaches also favoured megaprojects, which connected landscape transformation, modernisation, and state-building – again especially with respect to creating and expanding irrigation (Josephson, 1995; Molle et al., 2009), such as in the American West (Worster, 1985) or Spain (Swyngedouw, 2015) in the 20th century. As Swyngedouw (2015) and Harvey (1996) argue, modernisation projects always involve environmental transformation. The question for this paper is: what happens to the transformed environment in what Obertreis (2017: 482) might call the "ruins of Soviet modernity", i.e. after the modernisation project has crashed.

Thus, environmental history qua history of modernity offers several useful perspectives on agrarian change in this region that have not been fully explored. As Obertreis (2017) ably demonstrates, environmental history effectively historicises the pursuit of modernity, helping to divorce modernisation from a teleology of progress, and instead expose the contingencies and compromises with which modernity's proponents are forced to engage along the way. This is significant for several reasons. First, it helps in understanding how trends and variability under the Soviet era shape post-Soviet change. Even if much work on agrarian change makes implicit references to Soviet antecedents, there is still a general impression that the arc of agrarian change is from Soviet uniformity to post-Soviet diversity. Taking a longer view – as for example Ioffe et al. (2006) does with respect to agriculture, or Derlugian (2005) does with respect to post-Soviet class formation and conflict – foregrounds the possibility that some of the seeds of post-Soviet difference were planted in the Soviet era (Stenning and Hörschmann, 2008). Second, environmental history helps to situate developments in remote villages in Southern Ukraine within a global context, which aids in understanding agrarian change in these villages. This is not to uncritically adopt the claims of late Cold War convergence theories that the Western and Eastern blocs were converging towards 'modern', industrialised societies (Lane and Lane, 1976), but to move beyond east-west binaries (Hann et al., 2002), and instead frame communism and capitalism as different attempts to build 'modern' societies. In sum, because of the unavoidable compromises there is no single modernity, a realisation which helps to better delineate similarities and differences between different regions, countries, and economic systems. This is perhaps even more important to keep in mind with respect to the post-communist period, when a new teleology of progress reigns. I am speaking of 'transition', i.e. the notion that post-communist countries should be evaluated according to the degree to which they have become liberal, capitalist democracies. Critics argue that this 'transition' is tarred by a sense of Western "triumphalism" (Herschel and Forsyth, 2001: 574), and its tendency to "erase" the region's "particular histories and geographies" (Stenning and Hörschmann, 2008: 321).

MANAGEMENT SCRIPTS, MULTIPLICITY, AND THE NATURE OF IRRIGATION TECHNOLOGY AND FARM FIELDS

Few contest the notion that technology embodies the social relations that prevailed when it was created. ANT takes this one step further, holding that technology or objects have their own agency, that they 'act', obviously not with the same consciousness as a human actor, but nevertheless 'disciplining' other actors, shaping possible development paths for other actors entangled with this technology (Latour, 2007). This has proven to be evident with irrigation technology, which, as Mollinga (2010) writes, carries 'management scripts', prescribing how the technology should be used, at what scale of production, and towards what end. I want to extend this approach to take into account the whole field in which irrigation technology is emplaced.

Farm fields also carry management scripts based on their design, which reflect the prevailing agrarian power relations when they were designed (Johnson, 1976; Vogeler, 1996; Blomley, 2007). There are two relevant but contrasting examples where the original management script embodied in the fields, clashes with management concerns that arose later due to ecological problems or political changes. One example is the US rectangular grid, whose purpose was to facilitate rapid settlement of the American Midwest by dividing the land into a regular grid, the smallest ownership parcel of which was the 'forty', i.e. 40 acres or 16 hectares (ha) (Johnson, 1976: 66-67). Later, the inviolate ownership rights that the survey grid contributed to, made resource management difficult at a scale any larger than a single farm. As Johnson writes: "the significance of the watershed has been learned only after bitter experience" (1976: 202). In contrast, Vogeler (1996) describes how post-communist German efforts to promote small to medium scale family farming in East Germany foundered because, among other reasons, the large-scale farming landscape organised under GDR farm collectivisation proved to be ideal for large-scale, industrialised, commercial farms, on land leased from parcel owners. In both

cases, original management scripts clash with later needs. In the American case, the older geometry of ownership parcels has proven a challenge for larger-scale resource governance, while in the East German case, the older geometry of large-user parcels has proven to be an obstacle for the insertion of a finer-scale ownership geometry. This focus on fields and their long shadow of influence illustrates the costs of real agrarian change when landscapes – when seen as technology or infrastructure – eventually have to be reorganised to suit different configurations of users (Myrdal, 2014).

Not only water, but the very fields thus also represent technology, and have politics or agency. However, farm fields, with their plants, soils, and contours, are also clearly 'nature'. A field is a 'resource' like land or water, but it is also a multiplicity of other things. A lot of work by human and non-human actors and by institutions, discourses, plus the effect of the things themselves, is required to singularise and stabilise the nature of these resources, and to determine how they should be valued and used, and by whom. If the connections between the actors performing this work of singularisation are disrupted – by revolution, economic collapse, ecological damage, war, or technological breakthrough – a conflicted situation may arise. Richardson (2016) calls this the 'politics of multiplicity', where different groups vie for the right to redefine 'what things are', and thus control their use. In the absence of abrupt changes, even stable things change over time as institutions, technology, and power relations evolve, bio-physical nature shifts, and objects decay. In terms of resource materialities, this means that resources such as land and water "wax and wane". (Li, 2014: 589). They may be fixed spatially, but they are "fluid in time" (Widgren, 2007: 72). Singularisation is always haunted by latent potentialities threatening to rewire prevailing assemblages into something different. Given time, these potentialities will manifest themselves. The task for the researcher is either to find cases where stabilised assemblages have broken down, becoming 'matters of concern' (Latour, 2007) where there is no longer recourse to authority, and/or to document the shadow potentialities lurking behind apparently stable resource assemblages.

SOURCES

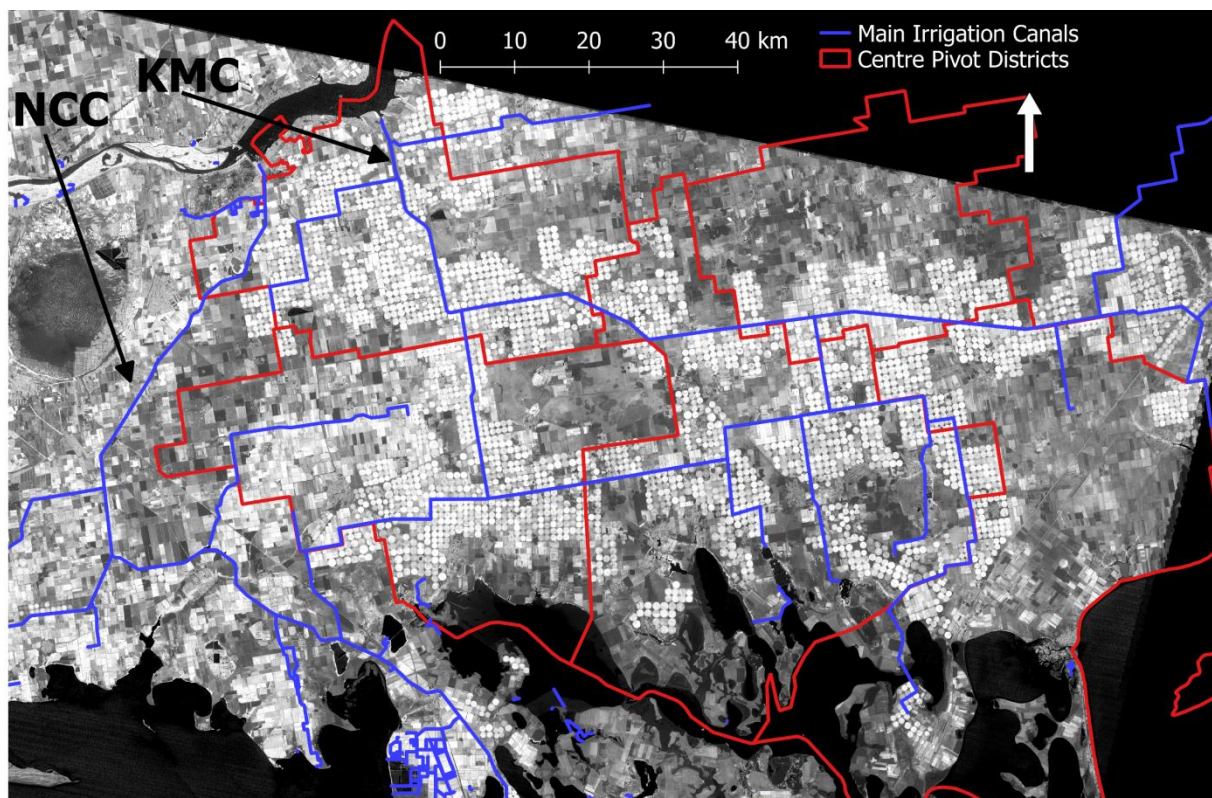
The sources used to map and trace changes in irrigation are an eclectic mix. First, 35 interviews were conducted with irrigation officials, village mayors, and farmers. Most of the latter owned or operated 'medium-sized' (in the Ukrainian context) commercial farms, from 300 to 7000 hectares, which is large by international standards but does not represent giant corporate farms. Interview guides were developed for different types of interviewees, i.e. irrigation officials, village mayors, and farmers. Ultimately, however, interviews were semi-structured, meaning that a number of follow-up questions – specific to the interviewee and the nature of the discussion – were also pursued in many of the interviews. For example, one farmer (quoted below), took me on a drive and then a walk through his fields, which presented an opportunity for a less structured conversation.¹ The interviews were conducted between 2010 and 2016, and they took place mostly in the centre pivot districts shown in Figures 2 and 4, though several interviews occurred just outside the western edge of this area along the North Crimean Canal (NCC). A second source of information is official statistics, obtained from the local branch of the Ukrainian State Statistics Committee. The author has acquired reports on irrigation from the years 2008 to 2014 (Derzhavna Sluzhba Statystyky Ukrainy u Khersons'koi Oblasti, 2009, 2010, 2011, 2012, 2013, 2014, 2015) and 1991 (Ministerstvo Statistiki Ukrainy, Khersonskoe Oblastnoe Upravlenie Stastistiki, 1991), which provide district-level information, specific to the different irrigated crops in the area. Also, the Kherson Oblast Water Resources Administration provided additional information on water use (see Figure 8). There is a persistent question about the reliability of post-

¹ Most of the interviews with farmers occurred in their offices - in many cases tens of kilometres away from their fields – which meant field walks were usually not a possibility.

communist statistics, which is addressed directly in this paper through a verification exercise involving satellite data (see below).

Another source is local newspaper articles, which were gathered from two of the five municipalities where centre pivots are concentrated: Kakhovs'kyi district (*Kakhovs'ka Zoria*), and Chaplyns'kyi district (*Radians'ka Tavria*). Where relevant, articles from regional newspapers (such as oblast-wide *Naddniprians'ka Pravda*) and other media outlets are used. Using such articles is not without its problems, as local newspapers, in a continuation of Soviet practice (Clark, 1993), are closely tied to local authorities and set their journalistic priorities accordingly. In other words, these newspapers generally present a sanitised image of various problems, and otherwise showcase what local authorities want to see in print. Even if they often succeed in presenting a sanitised view, official discourse about irrigation – often seen in the practices and results local leaders want to either praise or shame – are still of interest. Beyond this, I contend that the newspapers offer a glimpse into something else. Linton writes (2010: 9) that "ideas, meanings, laws, concrete fixtures, management techniques – hang together in a way that makes the hegemony of an idea seem natural, at least until confronted with a problem or contradiction that reveals it to be held in place by a web of powerful but ultimately changeable relations". I would argue, *à la* Linton, that the post-Soviet economic crisis was so palpable in the 1990s that officialdom, and newspapers reproducing their views, cannot but reflect – often using a variation of the phrase "in these complicated times" (see, for example, Bilik, 1997) – the 'web of powerful relations' desperately trying to hold 'things' together. In other words, newspapers provide some indication of the attempts of local elites to promote a particular kind of water use.

Figure 2. Normalized Difference Vegetation Index (NDVI) maximum-value composite, 1991.



Note: Each pixel in this image is the maximum value for that pixel among the five images constituting the time series (one each from June to October). The centre pivot *massiv* [massif or land] is clearly seen against the background of dryland agriculture. The main trunk lines of the two canal systems are indicated in the map: NCC = North Crimean Canal, and KMC = Kakhovs'kyi Main Canal.

A final source of information is satellite images. Using the same Landsat scene (path: 178/row: 28) from both the European Space Agency (ESA) and US Geological Survey (USGS) archives, separate time series (encompassing the entire agriculture season), were assembled for the years 1991, 2009–2011, and 2013 (see Figures 1 and 2).² These years are analysed because I had obtained corresponding official statistics on irrigation for those years. The minimum number of scenes per agricultural season was five (one per month from June to October), while the maximum number of scenes was 12, from May to October. Each scene was converted into a Normalized Difference Vegetation Index (NDVI), which is a biomass measurement widely used in crop yield remote sensing studies (Wardlow and Egbert, 2008; Funk and Budde, 2009; Becker-Reshef et al., 2010; Mkhabela et al., 2011). Visual interpretation³ was then employed to count the number of round fields where there appeared to be biomass (i.e. crops). The circular nature and large size of the centre pivot fields – usually 50 to 70 ha in size – made the counting procedure straightforward. The author is not aware of any other possible reason for sowing a field in a circle, except to prepare that field for centre pivot irrigation. Square and rectangular fields are another matter. Using only visual interpretation, it is often not possible to differentiate an irrigated square/rectangular field from a non-irrigated square/rectangular field, particularly in the spring or in a year with good rainfall. Hence the focus in this paper on mapping centre pivot fields, which constitute the bulk of the Kakhovka irrigation system.

This is not a GIS or remote sensing study. These images are treated essentially as historical photos, which was useful in two ways. First, it provided verification of official statistics, the reliability of which is questionable. In often calling for inventories of existing irrigation assets (Bilik, 1997; Gashchenko, 2004a; Menisenko and Zhilenko, 2011), officials themselves betray anxiety about the reliability of official information. Second, the images also corroborated both interview and newspaper accounts of what happened in particular villages with respect to irrigation.

CONSTRUCTING THE SOVIET WATERSCAPE OF TAVRIA

The novel *Tavria* is written in the 1950s when work had already begun on damming the Dnipro river in Southern Ukraine (as a first step towards extensive irrigation), but it is set just prior to the Bolshevik revolution. In the novel, a migrant labourer is trudging across the dry steppe to what was then the estate and farm of Askania Nova.⁴ He says to himself, "If only on this expanse there was enough water for everyone".⁵ (Honchar, 1954: 81). Though the character in the novel was a subject of the tsar, the comment reflects the Soviet commitment to make water available for everyone. Watering the steppe was not only a Soviet desire: there were discussions of possible methods of bringing water to this parched area before the revolution, though the conclusion was that it was not feasible because of prevailing technology at the time (Moon, 2013, 2016). Figure 3, below, which shows average monthly precipitation in Askania Nova, indicates how dry this area is.

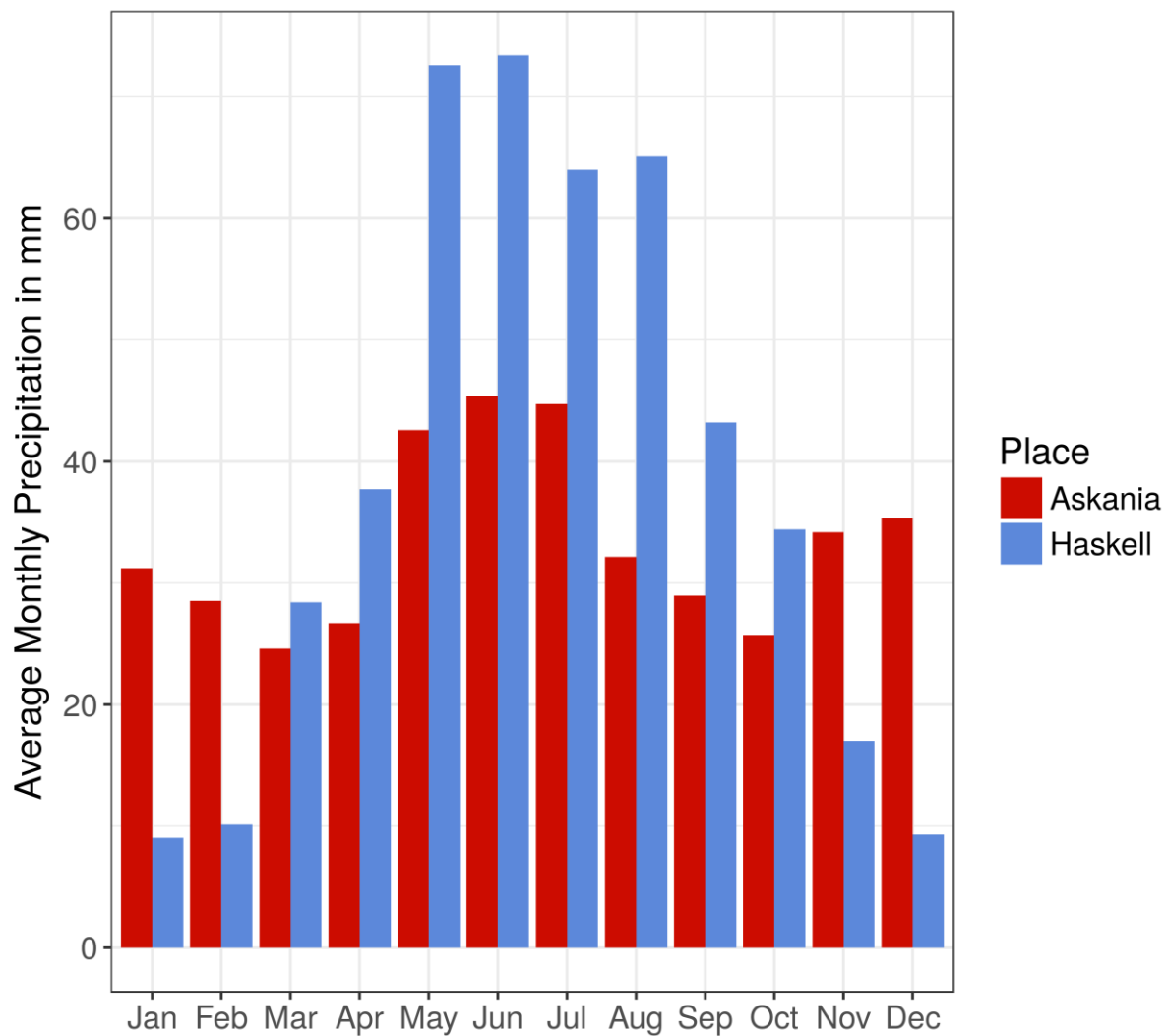
² ESA Landsat data was used for the 1991 growing season time series, while USGS Landsat data was used for all other growing season time series (2009–2011, 2013). The only other acceptable time-series (in terms of the number of cloudless satellite scenes) for the period under study were the years 2006 and 2000–2001.

³ Visual interpretation (or manual delineation) are still important methods in remote sensing, used, for example, by NASA (Herrick and Wren, 2017; see also <https://jmars.asu.edu/>) to count craters on Mars, an exercise which is not fundamentally different from counting centre pivots. This method, as shown below, proved adequate for the years 1991 and 2009–2013. However, a brief attempt to map and count centre pivots in 2000–2001 was abandoned because it proved difficult to visually separate unirrigated and irrigated fields, probably because, as indicated in Figure 8, much less water in general was being delivered to fields.

⁴ Askania Nova was converted to a nature preserve, or zapovednik, in the Soviet period, a status it retains to the present day and which accounts for why it is not irrigated (see Figures 3, 4, and 6).

⁵ The translation is mine. The novel was originally written in Ukrainian, but I have read it in a Russian translation: "(...) если бы на эти просторы да воды вдосталь (...)".

Figure 3. Comparison of average precipitation in Askania Nova and Haskell, Kansas (USA).



Note: The agricultural landscape of Haskell County, located in western Kansas, is famous for its many centre pivot irrigated fields (see, for example, this article from the *New York Times: Wines*, 2013), which is why it was selected as a point of comparison with Southern Ukraine, here represented by data from the weather station at Askania Nova. Both regions get relatively little precipitation, which, given the hot summers in both places, necessitates irrigation. The source for the precipitation data for Askania Nova is the Global Historical Climatology Network Monthly, Version 2 (Peterson and Vose, 1997), and the data used to calculate the monthly averages was from 1950 to 2004. The source of precipitation data for Haskell, Kansas, was *Climate Data Online*, a service of the National Centers for Environmental Information, of the National Oceanic and Atmospheric Agency (www.ncdc.noaa.gov/cdo-web/). Daily data from 1950 to 2018 was aggregated to calculate monthly averages. Annual rainfall in Askania Nova was, on average, 391 mm for this period, while for Haskell, Kansas, it was 462 mm, though the annual amount from year to year varied considerably for both places.

The cost calculus changed in the Soviet period when massive investments were made, first in taming the Dnipro river through the creation of a 'cascade' of dams, and reservoirs, and later in digging irrigation canals (Grigoryev, 1952; Lymar', 1997; Ushkarenko et al., 2006; Bashkeev, 2008; Gukalova et al., 2015). The NCC system, the first in left-bank Kherson, was completed in 1969. The purpose of the NCC, which stretches from the Dnipro River in Kherson Oblast into Crimea, was to bring fresh Dnipro water to Crimea for drinking water and irrigation,⁶ though it is also used for irrigation in south central

⁶ Due to the current conflict in the region, water from the NCC no longer flows to Crimea.

Kherson Oblast. Finally, the Kakhovks'kyi Main Canal (*Kakhovs'kyi Magistral'nyi Kanal – KMC*) was completed in 1990, forming the backbone of the Kakhovka Irrigation System. Water from the Dnipro River is pumped up 25 metres (Lymar', 1997: 58) from the Kakhovka Water Reservoir (the Dnipro) at the Main Kakhovka Pump Station, and from there flows by gravity throughout central left-bank Kherson Oblast, forking to the east, to neighbouring Zaporizhzhia Oblast, and to the south (Figures 2 and 4).

Essentially, a new landscape of water use in the dry southern tier of the Ukrainian mainland was created. The creation of this landscape is still celebrated today as a major achievement, not only allowing irrigation over a large area, but also regulating what once was the regular spring flooding of the Dnipro. This landscape was however not created without costs. Extensive wetlands along the Dnipro were heavily damaged – or disappeared altogether – in the construction of the dams and water reservoirs. Also, it is important to note that this landscape was created under particular communist conditions where energy was in effect, 'free', and prison labour could be exploited to create the canals.⁷ The Kakhovka Irrigation System delivered water to areas that, with the exception of territory near the Dnipro, truly had otherwise been dry, and where the main pre-revolutionary land use had been extensive grazing. However, large parts of the NCC (including the part of the NCC that is in the western part of Kakhovks'kyi district) overlay an area where there had been some 'local'⁸ or 'oasis' irrigation (Petrovskii, 1926) prior to the development of large-scale irrigation works, primarily based on proximity to the Dnipro and/or exploiting good quality aquifers that were close to the surface. Collective farms were encouraged to use ground or artesian water where available (Butenko et al., 1971) and from its modest beginnings in the late imperial/early Soviet period, this type of irrigation became, by the 1970s, a major source of irrigation (Ushkarenko et al., 2006: 18, 26).

Before the use of centre pivot irrigation machines in the USSR, irrigation in Southern Ukraine was carried out mostly by Soviet-designed DDA-100 sprinklers, though along the NCC there was even older Soviet technology in use. DDA-100s connected to temporary ditches, and advanced linearly up and down long, rectangular fields (Kriulin et al., 2003). It was (and is – a few are still in use) not possible to adjust the amount of water being applied to the fields with the DDA-100, which became problematic. Flooding caused by rising water tables was a widespread problem in the early years of irrigation along the NCC. E.A. Bashkeev, at that time head of the Ukgiprovdokhoz Institute in Kyiv – the institution which proposed and planned the Kakhovka irrigation system – believed that the DDA-100, while not the main cause of the flooding, did contribute to the problem (Bashkeev, 2008). To avoid these problems in the future, centre pivot irrigation was implemented for the Kakhovka system. Interestingly, the technology was licensed from the American company, Valley Irrigation, in the early 1970s, though the Soviet centre pivots were (and still are) produced under the name 'Frigate' (*fregat*). Bashkeev describes how the engineering team planning the Kakhovka system studied a variety of different foreign irrigation systems at an exhibition in Kakhovs'kyi district, including Valley centre pivots, remarking that in comparison "our Ukrainian [technology] looks prehistoric" (Bashkeev, 2008: 114). Bashkeev came to the conclusion that the Valley centre pivots were best suited for Soviet purposes, mainly because they could be run automatically. He then convinced P.E. Shelest, the then head of the Ukrainian communist party (1963-1972), of the need for Valley centre pivots, who in turn sought and received approval for the acquisition of a production license for Valley centre pivots from the politburo in Moscow.⁹

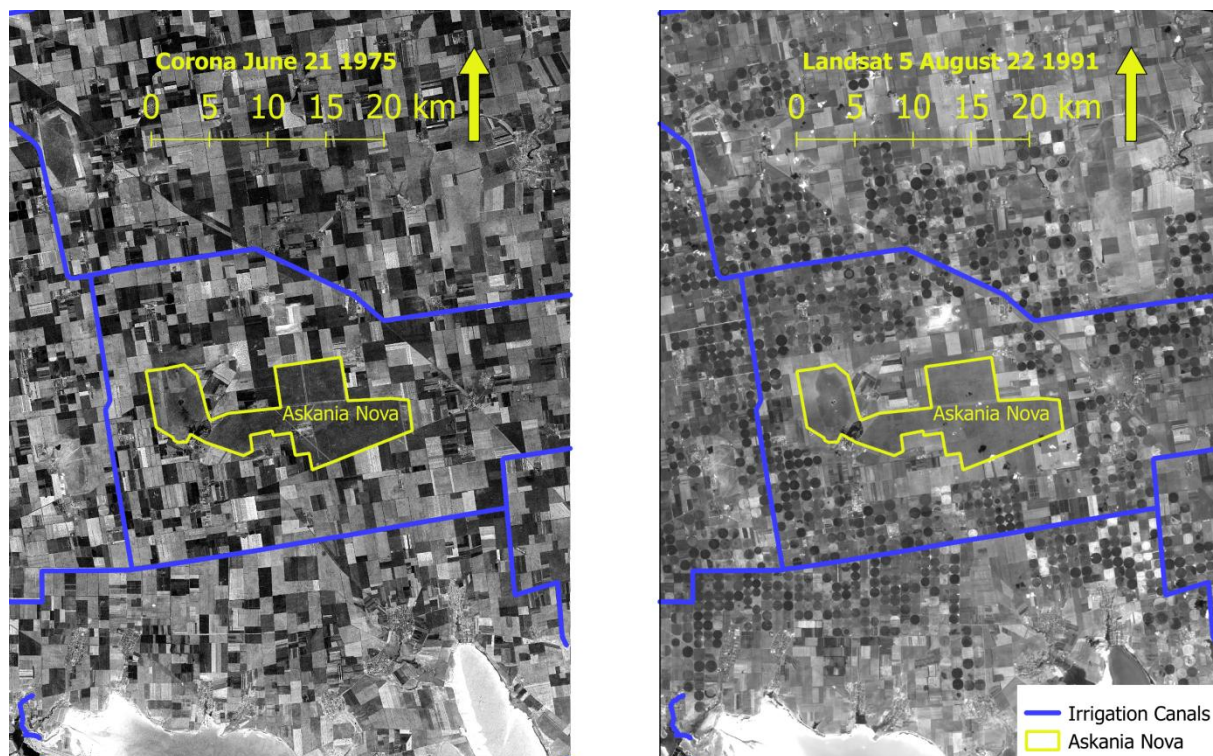
⁷ As in other major infrastructure projects in Soviet history, prison labour was used extensively for the construction of these irrigation canals. Tatiana, a witness to the use of prison labour for the canals, was interviewed for this study (Interview in Kherson city, 2016). She lived for some time in the village where many prisoners were kept. They lived in cramped wagons and were, as the interviewee stated, "very unhappy people".

⁸ In Russian, this kind of irrigation is referred to *mestnoe* (local) or *maloe* (lesser or small) *oroshenie* (irrigation).

⁹ Bashkeev offers no insight into the politburo deliberations, other than to say that he waited a long time (Bashkeev, 2008: 115) before receiving positive news on permission to use Valley centre pivots for the Kakhovka project. However, there is a

According to the factory where these centre pivots are still being produced, the formal decision to produce Valley-licensed centre pivot sprinklers was made in 1972 (Fregat Factory, 2018). Water is delivered under pressure (provided by regularly spaced pump houses) to the centre pivot through underground pipes; the pressurised water causes the centre pivot to spin, and the amount of water delivered to the fields can be adjusted. How the landscape changed after the installation of centre pivot irrigation can be seen in Figure 4.

Figure 4. Farming landscape 1975/1991.



Note: On the left is a June 1975 Corona image (USGS archive), while on the right is a Landsat 5 image from August 1991 (ESA archive). The image on the right is a grey-scale version of the true colour composite so that it resembles the black and white Corona image as much as possible. Most centre pivots were installed in the late 1970s and 1980s.

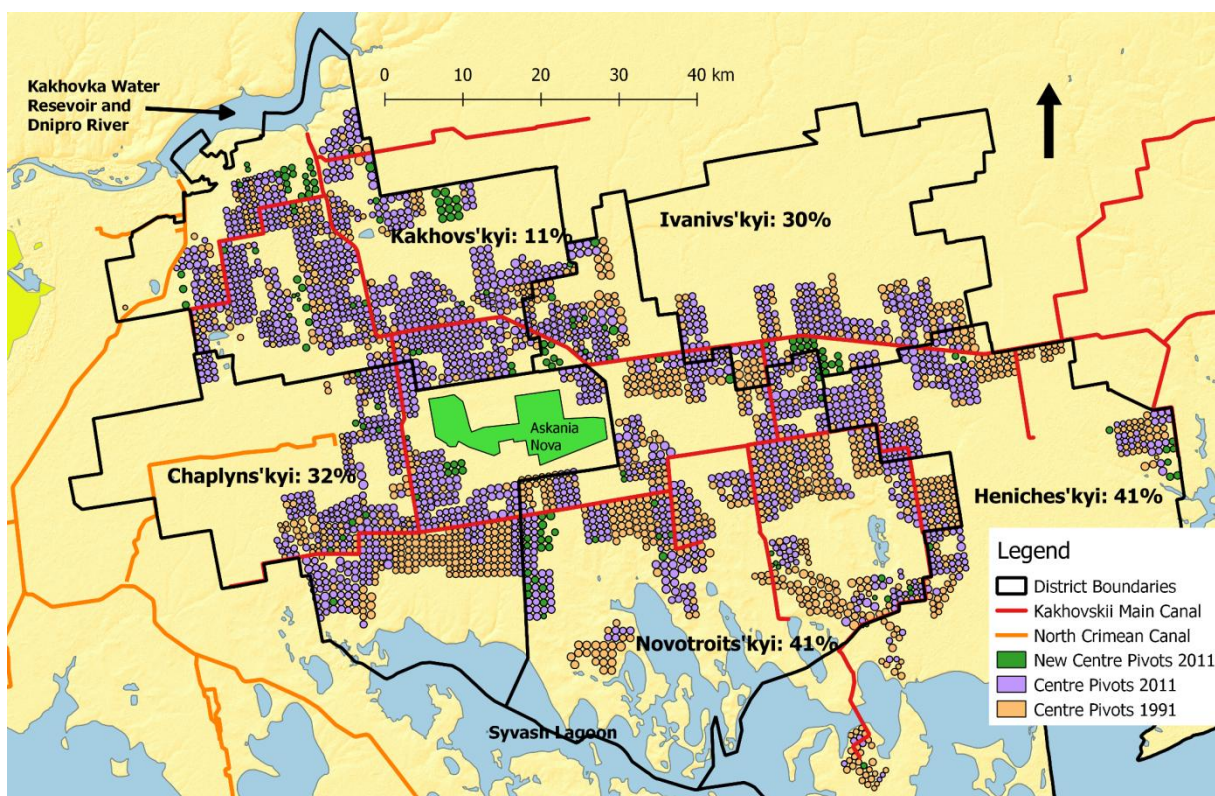
The Kakhovka system was completed in 1990, and there were ambitious plans to expand irrigation even more – with water from the Dnipro River – to all parts of the oblast. However, at that point the Soviet Union broke up into its constituent republics, and independent Ukraine entered into a deep economic crisis which lasted for much of the 1990s. Maintenance of existing systems became difficult, and even more so the development of new systems. There was also a degree of political chaos as a new political system took shape. Adding to the confusion in rural areas were land reforms, which began in earnest with the promulgation of a presidential decree in December 1999: "On priority measures for acceleration of the restructuring of the agrarian sector" (President Ukrainy, 1999). These reforms mandated that, first, collective farm fields be divided up and ownership given to collective farm workers (and pensioners). The average parcel size, considering all of Ukraine, is 4.2 ha (OECD and The World Bank, 2004: 86), though the actual size of the parcel depends on the size of the farm, quality of land,

long history of American exports of agricultural technology to the Soviet Union, and the licensing of the Valley centre pivots occurred at a time when there were extensive Soviet imports of American grain.

and number of beneficiaries per farm. Second, all collective farms were ordered to restructure and re-register as market-oriented organisations which would henceforth conclude lease agreements with the new landowners (Allina-Pisano, 2007; Lerman et al., 2007). Note that an important aspect of Ukrainian land reform is that the sale of agricultural land is still not permitted; the exchange of land occurs through lease agreements.

However, this individualisation of ownership of collective farm fields led to a tension between the disposition of irrigation equipment designed for the irrigation of a 50+ ha field, and ownership of the field itself, which was divided "like a chessboard" (Dubrovik, 2012) into 10 or more (depending on the field) ownership parcels (called *pai*) and distributed to former collective farm workers (Kuns, 2017). The 1999 presidential decree, which launched real land reform, says nothing specific about the status of irrigation infrastructure, though it contains a vague statement that authorities should seek to "preserve, where possible, the integrity of the use of the land and assets of former collective farms". (President Ukrainy, 1999; translation mine). Article 26 of the Ukrainian Land Code, promulgated in 2002, states that land with irrigation assets must be used jointly when privatised, but by this time much irrigated land had already been privatised, and the status of this statute with respect to already-privatised land is unclear (See Miroshnichenko and Marusenko, 2009: 112-113).

Figure 5. Comparison of centre pivot positions 1991/2011.

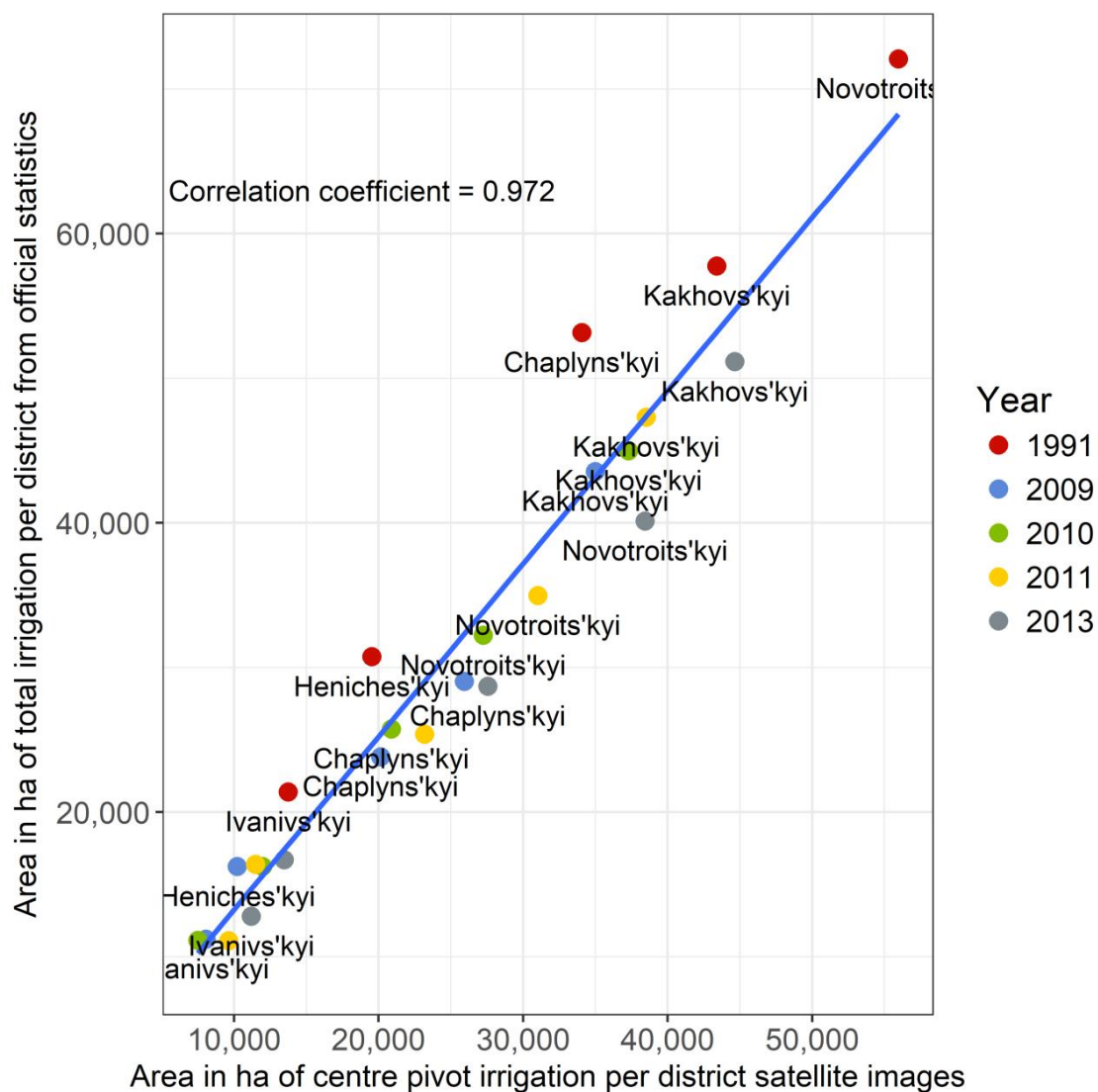


Note: Orange circles represent centre pivot positions in use in 1991, but not 2011. The proportion of 1991 centre pivot positions that were not irrigated in 2011 is indicated in percent.

In the Soviet period, all irrigation equipment was listed as assets on the balance sheet of state agencies. In the early 1990s, the on-farm pipes and sprinklers and other equipment – the so-called 'on-farm network' (*vnutri-khoziastvennaia set'*) – were transferred to collective farms (Shatokhin, 1993). Meanwhile, the pumping stations (the inter-farm network or *mezh-khoziastvennaia set'*) remained

under the control of the Water Resources Department, while the canals remained under the control of separate canal authorities, all of which (the water resources department and canal authorities) are separate subdivisions of the Ukrainian Ministry of Ecology. When the land was privatised there arose a confusing situation as to who owned the on-farm irrigation infrastructure. On-farm irrigation equipment became 'no-one's' (*nicheinii*), according to the officials and farmers bemoaning this process. At the turn of the century, spare parts became hard to find, fuel and electricity became expensive, and looting of irrigation equipment commenced. Irrigation in Southern Ukraine teetered on the edge of total collapse. The irrigation system in Southern Ukraine, if judged by the situation in the late 1990s/early 2000s, aligns with the view described above, of Soviet environmental management as unsustainable. However, irrigation – as documented in the next section – would be revived.

Figure 6. Comparison of different calculations of total irrigated territory in five districts of Kherson Oblast.



Note: The x-axis is the author's count of centre pivot fields, identified in satellite images, while the y-axis counts all irrigation (centre pivot plus other forms), based on official statistics from the Ukrainian State Statistics Committee, Kherson office.

CENTRE PIVOT IRRIGATION 20 YEARS AFTER SOVIET COLLAPSE

Figure 5 shows the state of centre pivot irrigation in 2011 and 1991, based on the counting exercise described above. Overall, 3066 centre pivot 'positions' were counted in 1991, and 2104 in 2011. However, 164 positions are new in 2011, i.e. not irrigated by centre pivots in 1991. There are two main areas of such new centre pivot irrigation – one in north-central Kakhovks'kyi district, and one in Ivanivs'kyi district close to the canal. In total, some 63 percent of 1991 centre pivot 'positions' are being irrigated by centre pivot sprinklers in 2011. The 37 percent that has gone missing has a distinct geography. Kakhovks'kyi district has only lost 11 percent of its centre pivot positions, while the two districts furthest to the southeast have each lost 41 percent of their centre pivot positions. Figure 6 compares the irrigated area calculated by the author, based on satellite imagery and focusing exclusively on centre pivot irrigation (x-axis), with the officially reported irrigated area for the years 1991, 2009-2011 and 2013, including centre pivot and other forms of irrigation (y-axis). The two separate counts appear to align well, with a correlation coefficient of 0.972. In other words, the results of the counting exercise would suggest that official statistics on the amount of territory irrigated are reliable. It can also be stated that centre pivot irrigation was the dominant form of irrigation in 1991, and remains dominant in the period 2009-2013. However, these figures say little about what caused some irrigation in this area to disappear. This is taken up in the next section.

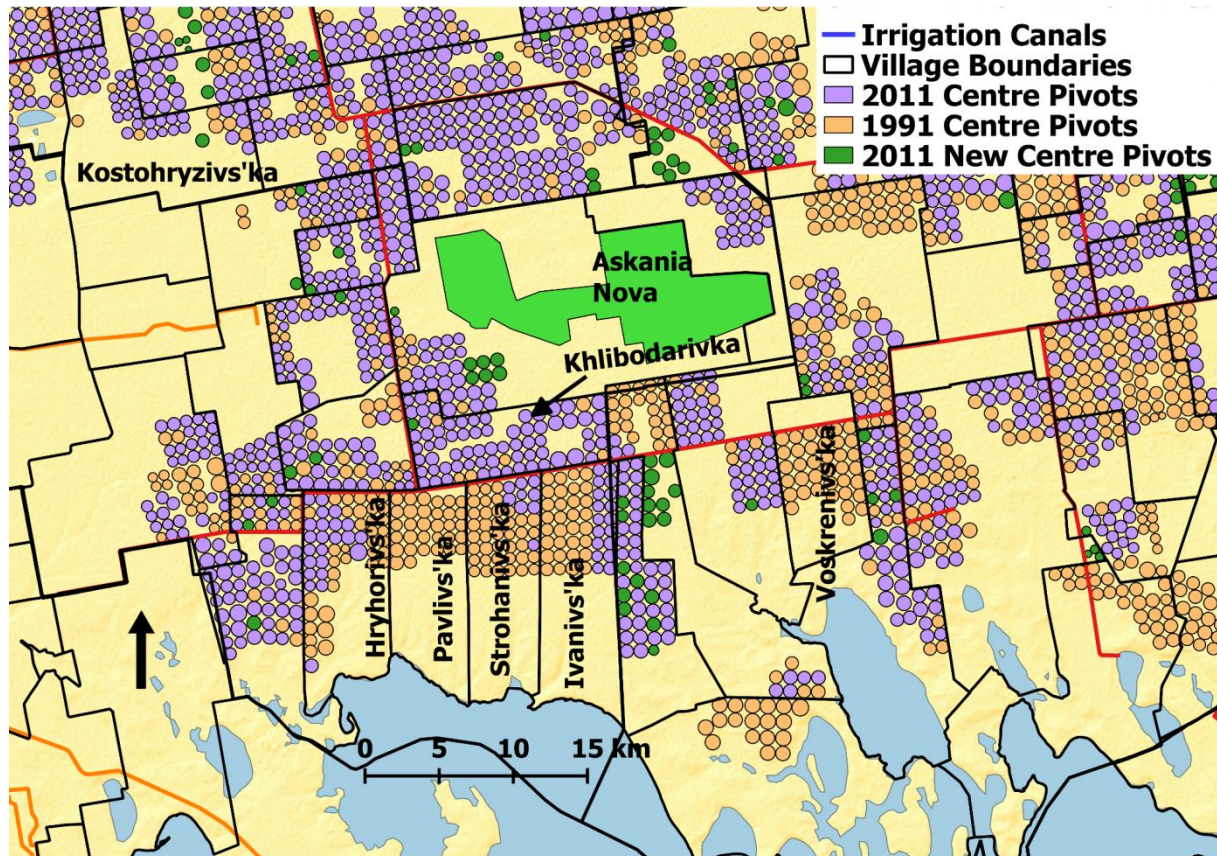
BATTLE FOR THE FIELDS I: "AGAIN POWER CHANGES HANDS"

The Chaplyns'kyi district newspaper *Radians'ka Tavria* (Soviet Tavria) reported in March 2001 (Beserab and Gmiriya, 2001) on the process of farm restructuring in the village of Pavlivs'ka (Figure 7), where three companies – including the ailing successor to the collective farm, now organised as a private cooperative – were vying for lease contracts which were to be granted by the landowners in the village. In the meantime, the authors write, the systematic stripping of anything metal in the village, including farm assets, had been 'progressing' for some time. As an overall description for what is going on in the village, with farms being replaced by new farms in rapid succession, the authors invoke the popular Soviet film *Wedding in Malinovka* (1967). In the film, which is set in Ukraine during the civil war between Reds and Whites that followed the Bolshevik revolution, the fictional village of Malinovka rapidly changes hands between White and Red soldiers several times, causing the village mayor to either take off his peaked communist cap or put it on, grumbling (in the film's signature line), "again power changes hands". Changing tone, the article continues: "since time immemorial our land has been fought over". Though this particular formulation in the article reflects an oft-repeated sentiment, the description of the situation in this village as a battle for the fields is apt. This section will detail how fields in part of the centre pivot *massiv* [massif] (to use a standard Russian expression) were subject to an occasionally violent conflict. At the outset, I note that Pavlivs'ka lost all centre pivot positions between 1991 and 2011, and the question is what caused this to happen in Pavlivs'ka and in other villages?

In the local news in the 1990s, irrigation and district officials offered different reasons for the disappearance of irrigation equipment: the age of the equipment, lack of spare parts, and fuel shortages. Another cause, which occurred occasionally after land reform, was a judicial decision against the owner (if identifiable) resulting in irrigation equipment being sold for scrap to pay debts. However, the main reason – based on an overall assessment of the interview and news reports – is the looting of equipment to sell as scrap. This assessment is based on news reports specifically citing looting as the main cause in specific villages. Thus, in a 2006 article in *Radians'ka Tavria* (Beserab, 2006) the journalist blames looters for removing the underground pipes delivering water to the fields of Hryhorivs'ka, Pavlivs'ka, Strohanivs'ka and Ivanivs'ka in Chaplyns'kyi district. Indeed, looking at Figure 7, we see that the vast majority of centre pivot positions present in 1991 in these villages are not present in 2011. Other news reports confirm this, such as a report from *Radians'ka Tavria* in 2004 (Vorobiova, 2004),

specifically mentioning the villages of Strohanivs'ka, Ivanivs'ka and Pavlivs'ka. Also, Figure 7 confirms the statement of an irrigation official who is quoted in 2002 in the oblast-wide paper *Naddniprians'ka Pravda* (Bilik, 2002), saying that the irrigation system was completely looted in the village of Voskrenivs'ka, which is close to Pavlivs'ka, but is actually in the neighbouring Novotroits'kii district.

Figure 7. Close-up showing which villages have lost/retained centre pivot positions.

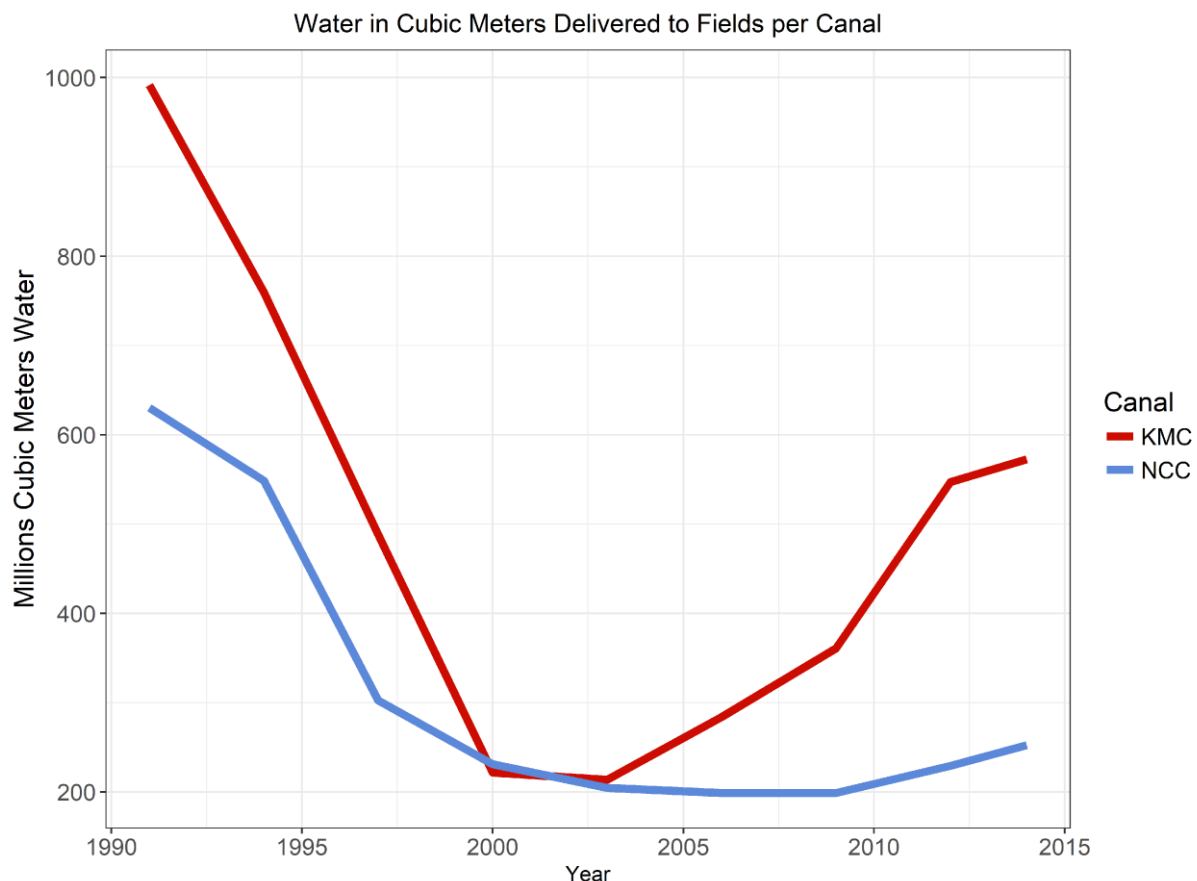


While official discourse identifies looting as a main cause for disappearing irrigation equipment, it is a less reliable guide for identifying the root cause of the looting, and who the looters were. Irrigation and district officials attribute the looting to the legal discrepancy that arose when the fields were divided up among different owners, but the irrigation equipment, previously belonging to now-liquidated collective farms, became 'no-one's' (Bilik, 1997; Gashchenko, 2004b). Evidence in support of this theory is that the period of mass looting ended around 2003 (though isolated cases still occur), when an inventory of irrigation assets was conducted, and, thanks to a resolution of the Ukrainian Cabinet of Ministers, ownership of irrigation equipment was assigned to villages or districts (Kabinet Ministriv Ukrainy, 2003). Another piece of evidence is the village of Khibodarivka (see Figure 7) where, in addition to assigning ownership of the fields during land reform, village authorities also assigned ownership of irrigation assets. This, according to Danishevskii (2003), writing in *Radians'ka Tavria*, was actually a violation of existing laws at that time, because procedures for the distribution of collective farms' movable property had not yet been decided. Be that as it may, Danishevskii reports that, in contrast to neighbouring villages where irrigation systems were being removed "with knives and horns", owners of irrigation equipment in Khibodarivka took measures to protect their equipment. Also, an interviewee, who farms 3000 ha in different parts of Chaplyns'kyi district, approvingly cited the villagers of Khibodarivka, stating that when they visited Khibodarivka looking for land to lease, they

found the centre pivot fridges in good condition "standing like brides" (Interview in Chaplyns'kyi district, October 2015).

There are indications, then, that a legal vacuum has contributed to looting. This explanation may be popular because it places the main responsibility on reformers in Kyiv who did not think through all the consequences of land reform. I will now present evidence that identifies a broader set of circumstances and actors complicit in this drama, a complicity which can be placed closer to home. There are three overlapping lines of evidence for this broader story. The first is that already in 1998, before the main land reform, farms in the looted villages in Chaplyns'kyi district (particularly Pavlivs'ka) – including still-functioning (if barely) collective farms – could be identified as among the worst-performing in the district (see, for example, *Radians'ka Tavria*, 1998). The main reason appears to be that most of the irrigated fields in these looted villages were already not being irrigated (Puliaieva, 1998a). This article does not mention the cause of idle irrigation, but another article in 1998, examining the state of irrigation in the district, states that "not a little amount of irrigation equipment is out of order thanks to the hunters of light metals" (Puliaieva, 1998b).

Figure 8. Amount of water (in millions of cubic meters) delivered to farm fields by the Kherson Water Authority per canal.



Source: Kherson Water Department. Note: KMC = Kakhovks'kyi Main Canal; NCC = North Crimean Canal.

The second line of evidence concerns the scrap metal trade. A number of articles from this period bemoan the stripping of everything metal in villages, and the sale of this material for scrap (See, for example, Beserab, 2001; Beserab and Gmiriya, 2001; Rudenko and Menisenko, 2004; Yanovskii, 2008).

Judging from these articles it is possible to make four observations. First, metal looting is an organised business. Second, while one journalist ascribes this activity to "thieves" and "con artists" (Beserab, 2006), other articles identify either unemployed villagers or people from neighbouring villages as workers in the scrap metal trade (see for example Puliaeva, 2004a; Vorobiova, 2004). The reason people trade in scrap metal is attributed to unemployment (Rudenko and Menisenko, 2004; Vorobiova, 2004). Third, while not all articles complaining about the scrap metal trade mention irrigation equipment specifically – though they do describe the stripping of metal from other pieces of agricultural infrastructure (Puliaeva, 2004b) – Chaplyns'kyi district officials declared in 2004 (Vorobiova, 2004) that in order to end the looting of irrigation equipment they would close scrap metal businesses operating in the district. Finally, though several articles (Beserab, 2001; Vorobiova, 2004) refer to police complaints being made about looting, and even culprits being taken into custody, not one article was found indicating that anyone had been prosecuted for looting. On the one hand, complaints about looting were aired in the local press, but on the other hand, some district authorities, for whatever reason, appear not to have been active in policing this activity until 2003-2004. In this context, it is important to note that the scrap metal trade is a widespread phenomenon in other post-Soviet republics (Bendiksen and Matsen, 2002; Bardzimashvili, 2013). Like Ukraine, irrigation systems were extensively looted in the Republic of Georgia (Wyeth, 2016).

The third line of evidence concerns violence between looters and the guards who are protecting irrigated fields in use. Several respondents mentioned this, including one respondent who referred to gunfights around his fields in the late 1990s/early 2000s when looting was most intensive (Press Conference with Farmer from Hola Prystan', 2016).¹⁰ Also an article in 2009 in *Kakhovs'ka Zoria* described how a guard for an irrigated field shot and killed a metal looter (Tribushnaia, 2009).

The official explanation stresses ownership, while this alternative explanation stresses use. An interviewed farmer in Kakhovks'kyi district said that in the 1990s many people no longer believed that agriculture was a profitable, worthwhile activity (Interview with farmer in Kakhovks'kyi district, 2010). This is in line with a general feeling at the time that agriculture was, as Barnes (2006: 204) – speaking of Russian agriculture – writes, "a hopeless morass of abysmal productivity". In other words, during the most intense period of land reform and farm restructuring (the late 1990s and early 2000s) when collective farms were collapsing, fields were being abandoned, villagers were finding themselves unemployed, and a legal vacuum developed with respect to ownership of irrigation assets, fundamental questions were raised about what is the point of farming, even what should be done with the fields. Some people did see the possibility for profitable agricultural production, while others, when they looked at the fields, saw scrap metal. Occasionally these two groups fought with each other. To put this in terms of the ontological politics of resource materialities, in a situation where there is collapsing authority, where 'power is changing hands', latent potentialities with respect to the existing resource base show up, and a "clash of divergent ontologies" emerges (Goodman, 1999: 30). As Tanya Richardson (2016: 146) writes, nothing guarantees that ontological politics will be an occasion for reasonable discussion. It can indeed be quite unpleasant.

Even if there are still scattered incidents of looting of irrigation equipment (Glavnoe, 2016), 2003 marks the turning point in this battle and the end of the period of mass looting, at least in the centre pivot *massiv*. Figure 8, which shows irrigation water along the KMC starting to increase from 2003, is indicative. This turning point likely reflects a lagged response to a general agricultural upswing that started in the early 2000s, which Lerman et al., (2007) credit to the land reforms that made it possible for investment to (re)commence in the agricultural sector. The general economic improvement that

¹⁰ This particular comment did not come from an interview, but from a press conference which the interview respondent participated in, the day after the author had an interview with him. The respondent invited the author to the press conference during the interview.

Ukraine experienced in the early 2000s certainly also played a role. Around this time, the state also began to actively support irrigated agriculture by, for example, compensating farmers for consumption of electricity in irrigation, which is the largest cost component of irrigation. Compensation began in 2004 (Mas, 2004), several years after farmers began paying market rates for electricity, and – with some irregularity – continued until 2012, when a post-financial-crisis economic slump, plus corruption, made it difficult to continue compensating farmers (Interview with farmer in Kakhovks'kyi district, 2015; Interview with farmer from Hola Prystan' district, 2016).

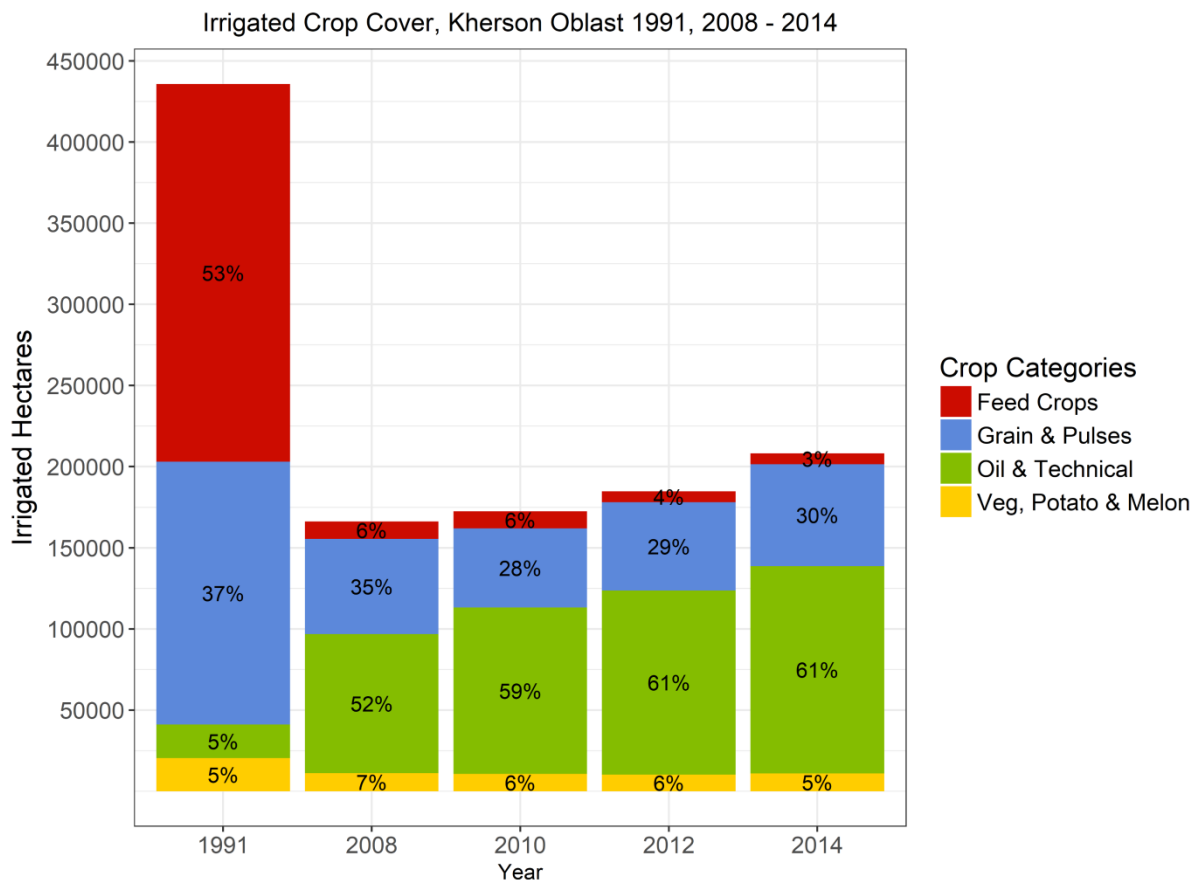
BATTLE FOR THE FIELDS II: WHO GETS TO USE IRRIGATED LAND AND AT WHAT PRICE

Not long after this victory, another battle formed along new lines. On the surface, this was a battle between large farms over access to irrigated fields. Under the surface, landowner rights were pitted against land-user rights, with land users ultimately appearing to win. An incident in 2011 in Kakhovks'kyi district illustrates this particular battle and its implications.

In 2011, a large farm in Kakhovks'kyi district, called Sudnoservice, wanted to expand. The problem was that all available land was taken. Sudnoservice tried offering landowners in two villages a higher lease rate – Rosdol'nens'ka, with no irrigation, and Kostohrizivs'ka, with irrigation (see Figure 7) (Kakhovs'ka Zoria, 2011). In theory, lease rates are determined competitively. In the absence of competition – a situation prevailing in many places in Ukraine (Demyanenko, 2005; Kuns, 2017) – the minimum lease should not go under three percent of the land's nominal value. In the author's experience, leases hover around the three percent norm, though for irrigated land there is a greater tendency to pay five percent. Sudnoservice was offering eight percent, an offer which convinced some villagers whose lease contracts with the farm Helios-1 were expiring, to agree to new contracts with Sudnoservice. This proposal caused consternation among farmers and local officials who, apparently fearing an increase in land lease costs, called for 'economically grounded' lease rates (Lugans'kii, 2011; Martiniuk, 2011). The problem however was that Sudnoservice did not acquire entire irrigated fields in Kostohrizivs'ka, but only parts of two irrigated fields. This made it difficult for either farm to use the fields, and Helios-1 actually tried to prevent Sudnoservice from accessing the fields in question. District authorities eventually intervened, hosting a summit meeting between the involved farm enterprises. The solution, according to *Kakhovs'ka Zoria* (Menisenko and Zhilenko, 2011), was that Sudnoservice and Helios-1 would jointly use the fields in question.

This solution is a less interesting aspect of the conflict than the rhetoric which emerged from the summit meeting. Thus, the head of the Kakhovks'kyi district land committee (the local organ certifying lease contracts and regulating land relations) stated that: 1) farms, in the event of conflict over land, should try to agree amongst themselves and avoid going to court, because "they [the courts] do not have expertise" (ibid); and 2) lease rates should not be driven up irresponsibly. In line with this, the *Kakhovs'ka Zoria* article features Sudnoservice walking back the promise of lease rates at eight percent. Moreover, the head of the KMC expressed criticism of small-scale farms using irrigation, and he suggested that only large-scale farms should have access to irrigated fields "because it is easier for us to deal with large farms" (ibid). He also argued that owners of parcels of land in irrigated fields who seek to withdraw their parcel, thereby obstructing irrigation of the entire field, should have to pay a penalty.

Figure 9. Total amount of irrigated land in Kherson Oblast, divided by crop cover, 1991, 2008, 2010, 2012, 2014.



Source: *Derzhavna Sluzhba Statystyky* (2009, 2011, 2013, 2015) and *Ministerstvo Statistiki Ukrainy* (1991). Note: The main feed crops grown in 1991, by far, were maize for silage and annual and perennial grasses.

These statements indicate a desire to create a regional class alliance which aligns the interests of district land and irrigation officials with those of large farms. This is an alliance favourable to the interests of large farms because it can potentially hold land lease costs down, while land and irrigation officials see large-scale agriculture as the best guarantee for preserving the infrastructure, which they are charged with maintaining. (It is worth noting that several respondents who were farmers, were also elected district or oblast council members.) Also, district officials appear to discriminate against landowners, particularly owners of land in irrigated fields, in favour of land users, in order to, as they see it, protect irrigation assets from fragmentation. As the then-head of the Oblast Water Department argued, speaking of centre pivot fields, it is not possible "to maintain the regime and technology" of irrigation on fragmented fields (Bilik, 2002). The chief irony here is that Ukrainian land reform, partially financed by the World Bank and USAID and thus representative of the Washington Consensus, is obstructed on irrigated fields by American irrigation technology.

Even if farms now pay for water, which is a significant change from the Soviet period, it is still important to note the unreformed nature of irrigation governance in Ukraine. The canal authorities and the water resources departments are direct successors to Soviet-era institutions. In the Soviet period, these institutions fell under the Ministry of Water Management, but were transferred to the newly formed Ministry of Ecology in the 1990s (Correspondence with official at Kherson Oblast Water

Department). They are, however, staffed by the same people, with new cadres obviously becoming more prominent in recent years (Ushkarenko et al., 2006). After the Maidan political revolution in 2014, a locally prominent foreign investor advocated the creation of a private water user association to govern the canals, but this effort was stifled by the local establishment – lawmakers from Kherson and some farmers (Zhilenko, 2014a, 2014b; Interview with farmer in Kakhovs'kyi District, October 2015).

Even as this points to important continuities with the Soviet era, i.e. support for large-scale farming, it is important to point out key differences in irrigation today. Perhaps the biggest difference is that completely different crops are now grown on irrigated land (see Figure 9). In the Soviet period, the chief purpose of irrigated land was to provide the livestock and dairy farming complexes with fodder, while the biggest crop category today is so-called 'technical' or oil crops, which, as shown in Figure 9, include sunflower seeds, soy, and rapeseed. Note that these crops are integrated into global markets – soy being directly exported, while sunflower seeds are crushed and processed into sunflower oil in Ukraine and then exported (though, as opposed to soy, there is considerable domestic consumption of sunflower oil). Soy, sunflower, and rapeseed are among the most profitable row crops, with some variation.¹¹ In any case, changing crop cover on irrigated land indicates that struggles over lease payments are actually struggles over the distribution of profits from agriculture, i.e. how much should go to landowners, and how much should be kept by users. As such, it seems almost 'natural' to expect that regional alliances would arise to try to protect this profit stream, as happened around the nexus of water and farming in Spain (Swyngedouw, 2015), California (Worster, 1985), and the southern Great Plains (Roberts, 1996; Cunfer, 2005).

THE REGIONAL CONTEXT: DIFFERENT WATERS FOR DIFFERENT GROUPS

Figure 8, which shows irrigation water use increasing along the KMC from 2003, and increasing in the area irrigated by the NCC later, is interesting for what it does not show. First, it does not show that villages experienced great difficulties in securing drinking water during the late 1990s and 2000s, including villages located within the centre pivot *massiv*. Newspaper reports from this time, and interviews with mayors from villages located near the KMC indicate serious problems in water delivery to villages, and refer to a sharp decrease in the amount of water available to villages compared to the Soviet period. There are a variety of reasons for this, but the main reason relates to farm restructuring. Collective farms built and maintained this infrastructure during the Soviet period (see *Radians'ka Tavria*, 2002; but many interview respondents confirmed this too). After farm restructuring, villages were supposed to create their own service providers to deliver water based on a fee scheme, while farms would no longer be responsible for such social functions. The problem was that neither villages nor districts had the funds to support the capital repairs needed for deep village wells, which in many cases were quite old, and there are many stories chronicling the decay of this equipment in villages, and even larger towns, situated in the centre pivot *massiv* (Puliaeva, 2004a; Bureiko, 2009; Zhilenko, 2009; Balabanov, 2011). Even if village water comes from deep wells and not the canals, it is ironic that, as water poured back into the fields in the 2000s, villages amidst these fields lacked water.

Second, Figure 8 is indicative of the irrigation activity of registered farm enterprises that have contracts with relevant district water departments for delivery of water to their fields. It does not, however, reflect water use in the informal sector, which is particularly pronounced near the NCC. Thus, while use of water sourced directly from the NCC has only increased slightly since the early 2000s (see Figure 8), there are indications that water use has increased considerably on tracts of land near the NCC (including land that used to be irrigated by the NCC), but that this increase is largely due to the widespread but informal practice of taking water from high quality, near-to-the-surface aquifers that

¹¹ For confirmation of this in English, see USDA Foreign Agricultural Service (2016).

underlie much of the NCC area. As such, it is not visible in official irrigation data. An indicator that is strongly suggestive of an increase of such informal irrigation near the NCC, as reported in Kuns (2017), is the sharp increase in (high water use) household vegetable production reported in official statistics in districts containing the NCC. These figures, which show a tripling of vegetable production for households in an NCC district between 2007 and 2013 (while the amount of land under vegetables holds steady), are likely to understate the amount of irrigation, as there are also a number of unregistered farms of varying sizes in this area, also tapping into ground water for the purposes of irrigation. The agricultural activity of so-called household farms (*khospodarstvo naselennia*), which are unregistered but lightly regulated small-scale farms of less than two hectares in size (Kuns, 2017) is at least tracked by official agricultural statistics. In contrast, larger unregistered farms are totally off the radar, both in terms of water use and production volumes. One such farmer who irrigates much of his 300 ha, which is located on territory that was originally irrigated from the NCC but no longer is, told me: "the state does not see me"¹² (Interview in Kherson Oblast, September 2016).

Access to water has, in other words, contributed to an expansion of irrigated farming at smaller scales of production in the NCC area. The important point here is that there is widespread access to water in the NCC area. There is also, of course, informal access to water along the KMC by farms or households located close enough to the canal to be able to take water without paying the relevant water department – indeed this is a source of vexation for the canal authorities (Menisenko and Zhilenko, 2011). Still, this informal use is limited to areas close to the canals, while aquifers of sufficient quality to be used for irrigation purposes in the area of the KMC are deeper, and therefore harder to reach, particularly for smaller operators. Near the NCC, private persons can dig their own wells and purchase pumps to lift the water. Such wells are usually unregistered – all wells whose purpose is not for 'household needs' are supposed to be registered with the Ministry of Ecology, and metered (Kuns, 2017: 493). However, the author has seen many unregistered wells being used for commercial farming purposes and, in any case, the existence of unregistered and unmetered wells is a well-known issue that was acknowledged by numerous respondents in this area. A primary driver of this informal water use, as reported in Kuns (2017) is the collapse of the collective farm sector and the resulting unemployment crisis.

A popular method of irrigation among farms using ground water near the NCC is drip irrigation, for several reasons. First, drip irrigation is suited to small-scale vegetable production where it can be adapted to fields of any size. Second, while no respondent expressed concern about depletion of ground water, pumping water is a significant expense, and drip irrigation does result in more efficient use of water pumped up from the ground (Interview in Kherson Oblast, September 2016). Finally, as reported by two respondents farming in this area, it is expensive to pump enough water from groundwater sources to irrigate row crops on a large-scale (Interview with farmer in Kherson Oblast, 2016; Interview with farmer from Hola Prystan', 2016). Thus, while physical proximity and ease of access to water are important factors shaping irrigated agriculture in this area, other factors are: weakened governance of resource use; the wide-spread availability of new (for the post-Soviet space) technology, allowing the efficient delivery of water to fields of any size and shape; and the prevalence of the informal economy, which allows marketing outlets for small-scale operations.

CONCLUSION: TECHNOLOGY, CONTINUITY, AND CHANGE IN POST-SOVIET AGRICULTURE

This paper has mapped continuity and change in centre pivot irrigation in five districts in the south of mainland Ukraine. To explain why some irrigation in this area has disappeared, I have described a

¹² No, the respondent has not read James C. Scott. This reply was after a line of questioning about informal economic activity, which I summed up with a final question: "So the state doesn't see you?", to which he answered as quoted above.

'battle for the fields' between farmers and looters, which determined whether farm fields would continue to be irrigated or not. I have then described a subsequent conflict over control of fields which has influenced which kind of users get access to irrigated fields and at what cost. These battles have been framed within ANT, which recognises that objects or technology have agency or politics, and that things like resources and infrastructure are almost always (even if subtly) haunted by multiple other possible definitions or configurations for use, providing potential avenues for change. This can be seen in the role played by American centre pivot technology, the politics or 'management scripts' of which are seen to prescribe a particular kind of farm unit – large-scale – in post-Soviet Ukraine, and which ironically contribute to a hollowing out of land ownership rights created by post-Soviet land reforms that were inspired by the Washington Consensus. In one sense the centre pivot fields are an example of rigidity, where the main alternative use was destruction and conversion into metal scrap. However, exemplifying the multiplicity of things, these fields also represent Soviet flexibility in procuring what was then state-of-the-art foreign technology for the improvement of Soviet agriculture, and while the scale of farm-units using centre pivots has not changed much, crop orientation and marketing patterns on irrigated fields have changed greatly, aligning considerably with international markets. If, to paraphrase the popular saying about irrigation, water flowed uphill to the fulfilment of the plan in the Soviet period, today that same technology clearly enables water to flow uphill to money.

In the meantime, while all water flowed to, and through, collective and state farms in the Soviet period, 'raining' on fields and plying villagers with drinking water, the disappearance of collective farms (due to farm restructuring) and new pricing schemes for water led to a fragmentation of this flow of water, such that water has now divided into different 'waters'. Water for irrigation along the canals is now on an upward trajectory towards Soviet levels, bringing with it big profits. Meanwhile, villages situated in this sea of irrigation are parched for drinking water because new pricing schemes, old and expensive-to-replace infrastructure, and lack of experience of new operators made it more difficult to extract water (though there has recently been improvement). However, to the west of the centre pivot area, near the NCC, where high quality artesian water lies close to the surface and the informal economy offers abundant marketing opportunities, village and farm taps are (probably) flowing as never before, though the actual amount of water used in irrigation is difficult to estimate because this occurs in Ukraine's shadow economy. Here there is innovation in technology (drip irrigation), and farm-size.

A variegated and uneven geography has arisen from the shadow of Soviet multiplicity. Despite this variation, there is in this case a logic to the unevenness, based largely on collective farm collapse and availability of water. If water comes from the canal, and there is centre pivot irrigation, then farms are mostly large-scale and in the formal sector. Villages in the KMC area, meanwhile, suffer because their drinking water comes from deep wells, and villages cannot afford to maintain the water-provision structure built by collective farms. If water comes from closer-to-the-surface underground sources, as for example near the NCC, farms are, relatively speaking, more likely to be smaller scale and in the informal sector. Here the collapse of collective farming has motivated people to intensify agriculture, which was facilitated by access to water.

More broadly, the use of American technology in Soviet agriculture, and the role that American technology has played in shaping land reform outcomes, underscores similarities between Soviet and post-Soviet farming and industrialised farming in the West. As Scott (1999) would argue, both represent continuing, but also evolving 'high-modernist' attempts to dominate nature through the intensive use of science and technology. Acknowledging similarity helps to situate Soviet and post-Soviet developments in the broader global context of 20th century investments in irrigation across the world. The timeline of the Soviet transformation of Southern Ukraine roughly coincides with the transformation of the American West by the US federal government (Worster, 1985; Cunfer, 2005) for the purposes of irrigation. One respondent in this study remarked that he had visited farms practicing irrigation in the US state of Washington, and he was shocked "at the Soviet prices American farmers

pay for water" (Interview with farmer from Hola Prystan', 2016). Even as the World Bank and USAID are trying to provide advice to Ukraine on how to manage irrigation, it may well be that irrigation in Southern Ukraine, built on a Soviet foundation and certainly not without its political and economic contradictions and injustices, is nevertheless more sustainable from an economic standpoint and from the standpoint of water use than irrigation in the western United States.

This study thus challenges the standard view mentioned in the introduction, of Soviet environmental management as a 'dark legacy'. The Soviet landscape of irrigation in Southern Ukraine has, in other words, proven to be more durable in post-Soviet circumstances than what one would have expected to proceed from the conventional wisdom, though the presence of, and access to, abundant Dnipro water certainly plays a role. The point of this is not, however, to argue that Soviet environmental management was uniformly better than the 'dark legacy' view. Rather, I wish to make two points. First, Soviet environmental management, and thus its legacy, was more variable than the standard view allows. Second, in order to understand the prospects for agriculture today in the post-Soviet space, irrigated or otherwise, we have to account for this variability.

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NOTE ON TRANSLITERATION

All Ukrainian words, including all place names, have been transliterated into English following Library of Congress (LOC) guidelines for Ukrainian. Russian words have been transliterated using LOC guidelines for Russian. This occasionally results in different spellings for the same word, depending on if it was a Ukrainian or Russian source.

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