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Conference Paper

Realizing the Benefits of ICT in the Climate Crisis: The Deployment Gap and Legal Impediments in Smart Agriculture and Water

29th European Regional Conference of the International Telecommunications Society (ITS): "Towards a Digital Future: Turning Technology into Markets?", Trento, Italy, 1st - 4th August, 2018

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Pearl, M. Alexander (2018) : Realizing the Benefits of ICT in the Climate Crisis: The Deployment Gap and Legal Impediments in Smart Agriculture and Water, 29th European Regional Conference of the International Telecommunications Society (ITS): "Towards a Digital Future: Turning Technology into Markets?", Trento, Italy, 1st - 4th August, 2018, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/184961>

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REALIZING THE BENEFITS OF ICT IN THE CLIMATE CRISIS: THE DEPLOYMENT GAP AND LEGAL IMPEDIMENTS IN SMART AGRICULTURE AND WATER

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Introduction

Information and communication technologies (ICT) hold the promise of mitigating and adapting to global climate change in a variety of different contexts. This article focuses on the implementation of ICT in two particular interconnected aspects of climate change: agriculture and water. Prevailing research identifies substantial possible anticipated benefits of “smart farming” that emphasizes more efficient use of water, increased crop production, and more effective utilization of time and other scarce resources in rural areas. The benefits of ICT integration into the agriculture market generally fall into two broad categories: improvements in prediction and efficiency.

Yet, the literature does not address three particular aspects of ICT integration: (1) the digital divide and the deployment gap, (2) the limited predictive power of real-time data, and (3) predominant legal paradigms promote maximum use of a resource.

The Digital Divide encompasses the idea that particular segments of the population, for a variety of reasons, are less able to access ICT. Typically, this focuses on underprivileged groups and underdeveloped countries. The rural nature of agriculture is particularly prone to challenges in accessing ICT, much less integrating it into their farming practices. There may also be cultural barriers to integrating ICT. Deployment of ICT in the agricultural market must be done through the usage of close-knit communities and the normalization of utilizing ICT. Beyond the cultural roadblocks, there are obvious economic costs to

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adopting “smart farming” practices that may not be readily recoverable in the market price obtained for their products.

In the context of the Climate Crisis, prediction plays a significant role in a variety of contexts. For example, the Intergovernmental Panel on Climate Change (IPCC) provides certain forecasts of global temperature increase based on greenhouse gas emission scenarios. Predictions are also used locally. Farmers, perhaps, were among the first to collect data and engage in long term predictions regarding temperature, frost, rainfall, and snowmelt. The problem with those predictions is that in the rapidly changing climate, they no longer hold because the principle of stationarity—that the future will continue to roughly resemble the past—is no longer operative. One of the benefits of ICT is the real-time availability of data concerning rainfall, moisture, weather forecasts and so forth. But, by definition, these predictions are subject to the scientific fact that the Earth is warming, thereby undermining the certainty and accuracy of any long-term prediction. The fact is, real time monitoring may not be able to assist in longer term predictions concerning changing rainfall patterns or how drought intensity will be affected.

ICT integration can provide agriculture with immediate data concerning critical aspects of farming, like soil moisture content, wind, temperature, and other variables that affect when, how much, and how often to irrigate crops. ICT can encourage the more efficient use of water resources. This is especially critical in the context of growing global and regional freshwater demands given population growth. In the context of the Climate Crisis and our adaptation to a warmer world with less water, we must learn to live with less water. ICT integration may result in more efficient water use, but not necessarily the conservation of water resources. Researchers can identify the optimal amount of water to be used in growing a type of crop given the region, climate, and other region-specific variables. ICT can facilitate when crops need to be watered, thereby reducing overwatering. Overwatering is inefficient from the sustainability perspective of global society, but it is also uneconomic from the farmer’s frame of reference.

Furthermore the property rights paradigm of the given locale may encourage the economically efficient use of water, but not the conservation of water. This undermines a primary objective in adapting to climate change. The goal is not to use the same amount of water more efficiently. The process of climate adaptation should focus on the transition to an

increasingly water scarce world. Thus, the objective should be on growing the same amount of crops with less water rather than using the same amount of water to grow more crops.

In order to address these gaps, the legal perspective is critical and undertheorized. By reviewing prevailing legal research on water rights systems and the underlying predominant property paradigms, I expose the deployment gap and show how integrating ICT does not necessarily result in progress towards the goal of adapting to climate change. In order to effectuate the full promise of ICT integrated agriculture, significant structural changes to water rights systems are necessary given the primacy of property rights in water. I will advance specific legal and political options for local, regional, and national governments that both close the deployment gap and encourage conservation rather than merely increased efficiency in water usage.

I. Snapshot of Global Freshwater

In 1997, the United Nations and the Stockholm Environment Institute prepared the Comprehensive Assessment of the Freshwater Resources of the World (CFWA).² Ninety-seven percent of the world's total water supply is found in oceans and seas—salt water.³ Of the remaining two and a half percent constituting global freshwater supply, roughly two-thirds exist in glaciers and in the snow covered polar areas.⁴ The remaining one-third of freshwater resources is found in rivers, lakes, and groundwater aquifers.⁵ By far, groundwater makes up the largest volume of available freshwater.⁶

Uitto suggests that, based on CFWA estimates, “by 2025 close to 5.5 billion people...will live in areas where the availability of good quality water will pose serious limitations to food production, economic development

² Comprehensive assessment of the freshwater resources of the world, Stockholm Environment Institute (SEI), 1997 (at: <https://www.ircwash.org/resources/comprehensive-assessment-freshwater-resources-world>).

³ *Id.*

⁴ *Id.*

⁵ *Id.*

⁶ Jac Van der Gun, *Groundwater and global change: Trends, opportunities and challenges*, United Nations Educational, Scientific and Cultural Organization 7, 2012 (at: <http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/Groundwater%20and%20Global%20Change.pdf>)

and social progress.”⁷ Familigiatti states that “two billion people rely on groundwater as their primary water source.”⁸ Critically, he also states that “half or more” of the water used to irrigate crops to produce food for the world comes from underground sources.⁹ Familigiatti concludes that the global groundwater crisis is underappreciated.¹⁰ Mainstream media’s coverage of this emerging crisis has increased recently, with major newspapers, documentary films, and other media have focused on groundwater scarcity in areas such as California, Texas, India, Morocco, and Peru.

The concern over the growing groundwater crisis is bolstered by the impact of climate change on the availability of freshwater resources and challenges to agricultural production. Groundwater is more than just a direct resource for extraction and use. In regions with available surface water—from lakes or rivers—during times of drought those sources may not be available. Groundwater serves as an important buffer for avoiding the devastation that drought may have upon an agricultural region. As global temperature increases, surface water resources will be stressed due to evaporation and the increased intensity, frequency, and duration of droughts—all of which are well known consequences of global climate change. This results in greater reliance upon groundwater resources to rescue communities from drought and dwindling surface water.

In 2001, the United Nation held a “World Day for Water” where speakers estimated that freshwater demands outpaced supply by fifteen to twenty percent and that within twenty-five years, two-thirds of the world’s population would experience significant water shortages.¹¹ UNESCO, in 2011, estimated that freshwater withdrawals from across the globe tripled over the past fifty years.¹² The cause of this substantial increase in demand is due to the increase of irrigated agriculture.¹³

A. *Snapshot: The Ogallala Aquifer and the State of Texas*

⁷ Juha Uitto, Global Freshwater Resources, World Forests, Markets and Policies pp 47-58, 2001.

⁸ J.S. Famiglietti, The Global Groundwater Crisis, *Nature Climate Change* volume 4, pages 945–948 (2014).

⁹ *Id.*

¹⁰ *Id.*

¹¹ Kenneth N. Brooks et al, Hydrology and Management of Watersheds 15 (2012).

¹² *Id.*

¹³ *Id.*

The Ogallala Aquifer is among the world's largest and most important groundwater aquifers. It stretches underneath eight states and more than 174,000 square miles.¹⁴ Groundwater extracted from the Ogallala allows for the irrigation of almost one third of the United States' cropland.¹⁵ Farmers in West Texas often refer to the Ogallala as "the lifeblood of this place."¹⁶ In June 2014, more than seventy percent of the state was suffering extreme or exceptional drought.¹⁷ The Ogallala Aquifer is currently overdrafted. The rate of recharge is already insufficient to meet the regional water demands, the sustained and significant drought has made matters much worse regarding recharge, the population continues to grow, and the demand for water by the irrigated agricultural sector and municipalities shows no sign of slowing.

Texas uses about 16 million acre-feet of water per year, with nearly sixty percent coming from groundwater.¹⁸ Almost eighty percent of the groundwater pumped in Texas goes toward irrigation.¹⁹ In the aftermath of World War II, Texas underwent a major revolution in irrigated agriculture.²⁰ Pumping of groundwater increased significantly.²¹ Over the course of the next 50 years, the population in Texas is expected to increase eighty-two percent, with a commensurate increase in the total water demanded, to an estimated total water demand of twenty-two million acre-feet per year.²² Ninety-six percent of the water pumped from the Ogallala aquifer in the Texas panhandle is used for irrigation.²³ Accordingly, the aquifer level has dropped—in some places overlying the Ogallala—up to

¹⁴ Arjen Y. Hoekstra, *The Water Footprint of Modern Consumer Society*, 34 (2013).

¹⁵ Pearl, *infra* n. 35.

¹⁶ Kate Galbraith, *Push Comes to Shove Over Water Restrictions*, N.Y. TIMES, Mar. 17, 2012, http://www.nytimes.com/2012/03/18/us/in-west-texas-push-comes-to-shove-over-water-restrictions.html?_r=0

¹⁷ *Everything You Need to Know About the Texas Drought*, STATEIMPACT, <http://stateimpact.npr.org/texas/tag/drought/> (last visited Mar. 4, 2015).

¹⁸ *Aquifers of Texas*, Tex. Almanac, <http://www.texasalmanac.com/topics/environment/aquifers-texas>.

¹⁹ *Id.*

²⁰ *Id.*

²¹ *Id.*

²² Tex. Water Res. Inst., *Water for Texas 2012*, Tx:H2O, 28 (2011), *available at* <http://twri.tamu.edu/newsletters/txh2o/txh2o-v7n1.pdf>.

²³ *Aquifers of Texas*, *supra* n. 18.

fifteen feet in the last ten years.²⁴ The Ogallala Aquifer is the poster-child for water scarcity and the harm caused by overuse in a region heavily leveraged upon agricultural production. Small towns all over West Texas and the High Plains are nearing extinction due to water shortages. The social and economic dependence upon agriculture—and thereby groundwater—is representative for regions, countries, and communities across the globe.

B. Climate Change, Groundwater, and Agriculture

Many agricultural regions depend upon groundwater for irrigation. Agriculture accounts for nearly 80% of water use globally, and as stated above, at least half of the irrigation water used is groundwater.²⁵ Increased global temperatures can decrease crop yields, increase irrigation demands, and changes in precipitation patterns can further stress groundwater buffers while increasing the likelihood of crop failures. Indeed, populations around the world already insecure in food and clean water availability will be further tested by global warming. A by product of the uncertainty and increased demands on freshwater supply is increased cost.

Researchers generally agree that more more work is needed in exploring the potential affects of climate change on groundwater resources—in comparison, much more work on surface water exists. However, Petra Doll’s modelling suggests that by the 2050s, groundwater resources may decline by ten percent globally, affecting more than one-fifth of the projected 10.7 billion global population.²⁶ Given current emissions trends, Doll suggests even stronger impacts could be expected.²⁷ Doll goes on to emphasize that the impact on available groundwater supply in already sensitive human systems and communities is likely underestimated in places like “India, Pakistan, Iran, Saudi Arabia, Jordan, Morocco and Tunisia, and in eastern China around Beijing.”²⁸

²⁴ Dennis Dimick, *If You Think the Water Crises Cant’s Get Worse, Wait Until the Aquifers Are Drained*, Nat’l Geographic Explorer, Aug. 19, 2014, <http://news.nationalgeographic.com/news/2014/08/140819-groundwater-california-drought-aquifers-hidden-crisis/>.

²⁵ Famiglietti, *supra* n. 8.

²⁶ Petra Doll, *Vulnerability to the impact of global climate change on renewable groundwater resources: a global scale assessment*, 2009 *Environ. Res. Lett.* 4 035006.

²⁷ *Id.*

²⁸ *Id.*

Regardless of the source of the freshwater, whether it be from rainfall, snowmelt, surface streams, or groundwater, climate change will affect agriculture. Agriculture is “highly sensitive to climate variation.”²⁹ Therefore, given the vagaries of predictions regarding specificity, intensity, and duration regarding local effects of global warming, many researching emphasize the value in building adaptive capacity to respond to changes in order to mitigate the damage done via crop failures.³⁰ As an example, Schauburger modeled wheat, soybeans, and corn production under climate change with increased temperatures and found that with more days per year during the growing season above 86 degrees Fahrenheit, harvests of those crops decline anywhere from twenty-two to forty-nine percent.³¹ The harm to crop production ultimately comes down to water stress. On hotter days, evaporation rates increase, which pull moisture from the soil, thereby requiring more water for the plant’s root system, and higher temperatures physically damage the plant leading to wilting.

While plants need carbon dioxide to grow, the increased presence of carbon dioxide cannot be construed in isolation apart from the other effects of higher temperatures on agriculture. However, as stated above, there is hope to adapt to these changing circumstance with the help of ICT.

II. ICT and Agriculture

²⁹ S. Mark Howden, et al., *Adapting agriculture to climate change*, Proceedings of the National Academy of Sciences Dec 2007, 104 (50) 19691-19696; DOI: 10.1073/pnas.0701890104.

³⁰ See, Howden supra n. 22; Tim Wheeler and Joachim Von Braun, Climate Change Impacts on Global Food Security, *SCIENCE* 02 AUG 2013 : 508-513; Harvey, C. A., Chacón, M. , Donatti, C. I., Garen, E. , Hannah, L. , Andrade, A. , Bede, L. , Brown, D. , Calle, A. , Chará, J. , Clement, C. , Gray, E. , Hoang, M. H., Minang, P. , Rodriguez, A. M., Seeberg-Elverfeldt, C. , Semroc, B. , Shames, S. , Smukler, S. , Somarriba, E. , Torquebiau, E. , Etten, J. and Wollenberg, E. (2014), Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and Mitigation in Tropical Agriculture. *Conservation Letters*, 7: 77-90. doi:[10.1111/conl.12066](https://doi.org/10.1111/conl.12066); Leslie Lipper and Phillip Thornton, Climate-Smart Agriculture for Food Security, *Nature Climate Change* volume 4, pages 1068–1072 (2014); Achim Walter, Robert Finger, Robert Huber, Nina Buchmann, Smart farming for sustainable agriculture, Proceedings of the National Academy of Sciences Jun 2017, 114 (24) 6148-6150; DOI:10.1073/pnas.1707462114

³¹ Bernard Schauburger et al, *Consistent negative response of US crops to high temperatures in observations and crop models*, 8:13931 | DOI: 10.1038/ncomms13931.

ICT and agriculture can be viewed as simply a new technological advancement for farmers. In essence, ICT is a tool—just like the development of more efficient methods of irrigation. However it focuses less on efficient delivery of water to plants, but on timing, of water delivery and the monitoring of plant health in general. Precision agriculture entails the deployment of monitors and sensors to collect real time data on soil moisture, humidity, temperature, light, and any other variable that affects crop growth. That data is hosted in the cloud and affords farmers the ability to access this data remotely. Advancements in automation and autonomous vehicles allow for the remote watering of plants, harvesting of plants, weeding, and other farming tasks at times that maximize the growth of crops. Drones can be employed to monitor crops, assess damage, blight, disease, and in some cases spray fertilizer or other chemicals that aid in crop yield. Real-time data collection and processing improves the efficiency of water use while putting farmers in the best position possible to readily adapt to unanticipated changes in climate.

A. *Predictions and Climate Change*

Bedrock scientific principles hold that the range of habitable climates for human beings (and plants) is limited. It is not simply the case that climate change will render one area of the world too hot to live in. The consequences of climate change go far beyond simply warming the planet to an uncomfortable degree. The increase in global temperature already has, and will continue to have, an effect on water resources.

Three primary areas of water resources will be impacted by temperature increase: enhanced surface water evaporation; modifying snowpack accumulation, location, and timing; and weather pattern changes including an intensification of drought. Changes to the availability of water resources—groundwater, surface water, rainfall, or snowpack—shakes the foundation of communities because the systems of water resources regulation have been built upon the idea of stationarity.

Stationarity, as used here, refers to “the idea that natural systems fluctuate within an unchanging envelope of variability.”³² This means that any variable, like stream flows in a river, has a time *invariant* function that

³² P. C. D. Milly et al., *Stationarity Is Dead: Whither Water Management?*, 319 SCIENCE 5863, (2008).

allows for future planning to be done on the basis of past measurements.³³ Some scientists assert that, in the context of water management, “stationarity is dead” and anthropogenic climate change killed it.³⁴ It is intuitive to see the problems that can arise when the Farmer’s Almanac is no longer very good at predicting rainfall for a given region. That makes the farmer’s job harder and riskier.

Predictions and forecasts are a part of everyday American life. Everything from the weather, the World Series, stock prices, and elections are the subject of predictions. Climate change has made predictions about rainfall, temperature, crop production much more likely to be incorrect. The consequences stemming from being wrong about fundamental life systems like available freshwater and food security are catastrophic. Since the past is no longer a reliable data set to utilize in planning for the future in the context of water resources the indirect consequences have an undefined reach and degree.

B. Flexibility and Response Time

Given the decreased reliability of predictions regarding availability of rainfall, snowpack melt, temperature, and weather patterns, it is more incumbent now, more than ever, that agriculture be able to respond quickly to significant changes in these areas. ICT truly represents an opportunity to mitigate the potential damage done to agricultural regions due to climate uncertainty.

With a warmer climate, and a less predictable growing season, the ability to deliver water efficiently—and only when the plant requires it—is critical to adapting to climate change. The customization ability afforded by ICT allows farmers to better combat uncertainty and increased heat. Indeed, ICT may emerge as a critical tool in developing resilience in the face of a warming world.

Two significant problems emerge that delay or prevent deploying ICT in the agricultural context. The “digital divide” is both a socio-cultural issue as well as an economic challenge. One concern is simply the cost of implementing ICT for small and family farming areas. Farming is not necessarily an immensely profitable industry, whose markets are often subsidized or heavily regulated by governmental authorities. Another

³³ *Id.*

³⁴ *Id.*

practical concern is that agricultural areas are generally quite rural, thereby calling into question the ability of cellular or other Internet providing infrastructure to allow ICT to truly function at its apex. Obtaining the necessary ICT components would be expensive, let alone the build out for such necessary infrastructure.

Finally, there are socio-cultural concerns regarding the demographic typically engaged in farmer. The digital divide is a longstanding concern regarding disparities among populations having access to technology like computers, mobile phones, and broadband Internet.³⁵ Sustained commitment to bridging this gap is necessary, says Menschel, which is difficult given the high human and financial cost of developing and implementing these technologies and the fact that progress in this area is challenged by “funding issues, short-term, piecemeal solutions” and competition from other issues that may be more acutely dangerous.³⁶ Mobile phone subscription has made inroads in developing countries where a twenty percent increased occurred from 2002 to 2007.³⁷

ICT is tool. Tools are only useful with adequate training and access to those tools. Developing the perfect ICT approach to precision farming will do no good if the bulk of the world’s population will be unable to deploy it. Precision farming ICT must be developed so that it may be used by individuals with varying levels of access to technology.

III. Climate Change Mitigation and Adaptation using ICT-1500

ICT can revolutionize agriculture—making it smarter and better able to adapt and respond to climate change and water scarcity. Indeed, it may become a necessity if one is to engage in agriculture at all. However, entrenched legal paradigms for water rights can thwart some of the benefits of ICT in important ways. Beyond simply allowing farmers to better react to unexpected changes in climate and crop needs, ICT presents some additional opportunities for governmental entities to monitor, regulate, and enforce the limitations of legal rights regarding water use.

³⁵ Brooke Menschel, *One Web to Unite Us All: Bridging the Digital Divide*, 29 Cardozo Arts & Ent. L.J. 143 (2011).

³⁶ *Id.*

³⁷ *Id.*

A. *The Problem of Water Rights and Climate Change*-750 (old)

The changes that come with temperature increase are bad enough by themselves. Indeed, the water-climate nexus is another example of how leveraged our climate is. But, the effects are exacerbated when they are situated within the legal context of water resource use and regulation, resulting in both physical and legal problems.

All water resources are subject to some degree of state, federal, or tribal sovereign control.³⁸ Water law is generally divided into two categories: surface water and groundwater. Each category is subject to potentially different rules regarding ownership and use of the water resource. For surface water, a typical state uses either riparian principles from English common law³⁹ or the doctrine of prior appropriation from American common law as legal structures.⁴⁰ Furthermore, water law generally exists within the realm of state law.⁴¹ Even where the watercourse, like the Mississippi River, traverses multiple states, each sovereign has the authority to regulate that portion of the river running through its boundaries.

The same goes for groundwater aquifers, like the Ogallala Aquifer, where water located in a common underground pool will be subject to different legal and regulatory structures.⁴² This fact of state regulatory control over common pool resources already produces difficulties in the context of regulating a watercourse in a sustainable fashion. One jurisdiction may have a different view of what amount of water may be

³⁸ Joseph W. Dellapenna, *The Evolution of Riparianism in the United States*, 95 MARQ. L. REV. 53 (2011); Jane Marx et al., *Tribal Jurisdiction over Reservation Water Quality and Quantity*, 43 S.D. L. REV. 315, 316 (1998).

³⁹ Lynda L. Butler, *Allocating Consumptive Water Rights in A Riparian Jurisdiction: Defining the Relationship Between Public and Private Interests*, 47 U. PITT. L. REV. 95 (1985); Dellapenna, *supra* note 28; Christopher L. Len, *Synthesis - A Brand New Water Law*, 8 U. DENV. WATER L. REV. 55 (2004).

⁴⁰ Lawrence J. MacDonnell, *Prior Appropriation: A Reassessment*, 18 U. DENV. WATER L. REV. 228, 229 (2015); Janet C. Neuman, *Beneficial Use, Waste, and Forfeiture: The Inefficient Search for Efficiency in Western Water Use*, 28 ENVTL. L. 919 (1998); Joseph L. Sax, *The Constitution, Property Rights and the Future of Water Law*, 61 U. COLO. L. REV. 257 (1990); Michael Toll, *Reimagining Western Water Law: Time-Limited Water Right Permits Based on A Comprehensive Beneficial Use Doctrine*, 82 U. COLO. L. REV. 595, 596 (2011).

⁴¹ Dellapenna, *supra* note 28. *But see* federally reserved rights, Robert T. Anderson, *Water Rights, Water Quality, and Regulatory Jurisdiction in Indian Country*, 34 STAN. ENVTL. L.J. 195, 196 (2015).

⁴² M. Alexander Pearl, *Tragedy of the Vital Commons*, 45 Env'tl. L. 1021 (2015).

diverted without undermining the long-term supply of water in the watercourse. The same holds true in the international context—the principle of sovereignty, *i.e.* that a country has the authority to regulate (or not) groundwater extraction within its political boundaries even though the aquifer is shared between two or more nations.

The fundamental problem with water law is that it imposes an inflexible property rights regime on an inherently variable resource. It attempts to create certainty out of uncertainty. This presents problems that water scarce areas already understand all too well. In general, there are two major types of legally cognizing water rights in common law systems: prior appropriation and riparianism. Under the doctrine of prior appropriation, the first person to put water to a beneficial use obtains a property right to the continuation of that use with the amount actually used.⁴³ So long as it is used beneficially, that right may not be abridged or limited by a governmental authority.

A riparian right to water use is much the same; as long as no harm is caused to other property right holders, the use may continue. These concepts are rooted in real property law—the use and enjoyment of property and the bundle of entitlements that come with ownership. Those property entitlements work perfectly well in the context of land, which does not move, evaporate, or cease to exist if sufficient rainfall or snowmelt does not materialize. The implicit and well-founded assumption is that each morning when a real property owner wakes up and looks out her window, her property will still be there.

Such a structure functions nicely by setting clear bright lines and well-defined rights that are separable and alienable. This, however, is not the *actual* state of things in the context of water resources. Perhaps such an approach functioned well in the water plentiful eastern United States, but not so in the west where water is more scarce. The problem of water scarcity that the western United States have grown up with is exacerbated by anthropogenic climate change. Uncertainty about the quantity and timing of rainfall and snowpack increases under climate change which thereby magnifies the inherent flaws in the property rights structure applied to water resources.

In many jurisdictions across the world, a person may obtain a water right to a certain quantity of water. They may also be locked into using

⁴³ Neuman, *supra* note 30.

that water for a particular use, for example, farming. If they wish to sell that water right to a municipality, they must first seek governmental approval. Let's consider the scenario where a farmer has a pre-existing water right for the purpose of agriculture. She uses their allotted amount to harvest their soybeans. She then invests, perhaps due to a governmental subsidy, in ICT for her farm. The infrastructure is present, she can view the needs of her farm remotely and respond autonomously and immediately. Imagine this efficiency results in a reduction of water consumption. She might simply wish to plant more crops, thereby internalizing the benefit of the ICT efficiency but not reducing her overall water consumption.

One of the fundamental goals of adapting and responding to climate change should be the conservation of water—not simply the more efficient use of the same amount of water. Water scarcity and stress are unaffected by the more efficient use of the same quantity of water. While this is a larger policy question, it is critical to emphasize that climate change requires adaptation and preparation for the likelihood of increased water scarcity which entails an attempt to reduce the overall consumption of water.

B. Enhanced Monitoring Ability, Regulatory Oversight, and Enforcement

Another benefit of ICT is the use by governmental entities responsible for enforcing legal limitations on water rights. The real-time data collection and monitoring of water use affords governmental entities the ability to assess water consumption by water rights holders. One of the problems with enforcing legal limitations on the use of water rights is monitoring an individual's water use. In water scarce regions with entrenched and well-developed property rights systems for water, like the western United States, regulators can better police water use by implementing remote sensing ICT to obtain real-time data collection. Regulators can require individuals to allow remote sensing ICT to be placed on the water right holder's property and allow the collection of data as a requirement of the water right. Upon realizing that an individual has exceeded the scope of the water right, regulators have a number of options including fines.

Of course, the challenge in this scenario is that climate change may have increased the need for water while the legal right to a quantity of water remains unchanged. This is especially problematic where the underlying use for the water is agriculture. Its likely that choosing to comply with the water right, rather than exceed it, would result in crop failure, thereby jeopardizing the food security or health of the surrounding community.

The deployment of ICT in the area water rights has a number of challenges, but also exposes the inherent flaws in a system of laws so heavily leveraged on the idea that water will be available and that the climate will not change.