Water Law Review

Volume 13 | Issue 1 Article 8

9-1-2009

Freshwater Resource and International Irrigation Policy and Reform: A Comparative Study

Rebecca Torres

Custom Citation

Rebecca Torres, Freshwater Resource and International Irrigation Policy and Reform: A Comparative Study, 13 U. Denv. Water L. Rev. 107 (2009).

INTERNATIONAL PERSPECTIVES

FRESHWATER RESOURCE AND INTERNATIONAL IRRIGATION POLICY AND REFORM: A COMPARATIVE STUDY

REBECCA TORRES*

* Rebecca Torres graduated from the New Mexico Institute of Mining and Technology with a Bachelor of Science degree in Business Management. She is currently a Juris Doctorate candidate at Texas Tech University School of Law, and also a Master of Science candidate at the Texas Tech University College of Agricultural and Applied Economics. She will graduate in May 2010. She was born and raised in the New Mexico Rio Grande Valley in a rural, farming region.

[Sheriff] Bernabé had gloomily called this meeting because he sensed a serious threat in Joe's beanfield. He had understood, as soon as he heard about the illegal irrigation, that you could not just waltz over and kick out Joe's headgate or post a sign ordering him to cease and desist. Because that... beanfield was an instant and potentially explosive symbol which no doubt had already captured the imaginations of a few disgruntled fanatics, and the only surprise about the whole affair, as Bernabé saw it, was, how come nobody had thought of it sooner?[1]

The Milagro Beanfield War develops the story of Joe Mondragón, a subsistence farmer in a small, rural, New Mexico town. The citizens of Milagro have financial difficulties, but they are content with their farming lifestyles. Joe, the main character, illegally irrigated his deceased father's beanfield, after the state re-appropriated his irrigation water further down the valley. The re-appropriation conveniently benefited a developer, who had plans to build a golf course and resort. Joe's dedication to the land, fashioned in John Nichol's novel, is an illustration of how important water is to the farmers who rely upon it, and the passion that they have for their way of life.

I. IRRIGATION AND FRESHWATER RESOURCE

Agricultural irrigation uses approximately 70% of the world's freshwater resources.[2] Both developing and already developed nations are using inefficient irrigation practices for a number of reasons including, but not limited to, poor management practices, outdated equipment, and lack of cooperation across transboundary watercourses. Therefore, the development of irrigation efficiency should be a top priority for all nations, because agriculture's use of freshwater resources constitutes a main reason for the world's water scarcity issues.

The problem, stated in its simplest terms, is that: (1) land available for agricultural use is decreasing; (2) water scarcity is on the rise; (3) the world's population is sustaining steady growth; and (4) as a result of the increasing population, demand for food is also increasing. Therefore, to successfully meet the demand for food, agriculturalists cannot continue with their current methods. Something must be done—farmers need to grow more crops on less land, while using less water. There is overwhelming evidence that the world's population will increase, and no evidence that global rainfall will increase, or that

1. JOHN NICHOLS, THE MILAGRO BEANFIELD WAR 37 (Ballantine Books 1976) (1974).
2. U.N. CONF. ON ENV'T & DEV., RIO DE JANERIO, BRAZIL, JUNE 3-14, 1992, *AGENDA 21*, ¶ 18.6 (1992), http://www.un.org/esa/sustdev/documents/agenda21/english/Agenda21.pdf.

freshwater resources will increase either.[3] Consequently, the only answer is to increase productivity and efficiency of agricultural practices.

Implementing this simply stated solution to the problem, however, is far from simple. Increasing productivity and efficiency is a complex task, especially because it involves multiple countries, with different crops and various watercourses. All of these countries experience different climates, rainfall levels, development, management, and governmental involvement. Take, for example, the following statistic: irrigation as a percentage of a country's total diversion of water ranges from only 2% to 4% in Poland, Canada, and Germany, but jumps to between 90% and 95% in Pakistan, the Sudan, Iraq, and Bangladesh.[4]

The information gathered and analyzed in this article is the result of several studies. As irrigation constitutes such a large portion of freshwater use throughout the world, many professionals, scholars, and institutions have researched and debated this topic. Two of the major players in international irrigation policy and reform research are the International Water Management Institute (IWMI) and the World Bank. IWMI has fifteen research centers around the world, working with policy makers, development agencies, and private organizations to improve management and productivity of freshwater resources worldwide.[5] The World Bank has conducted research on irrigation policy and reform and provides financial and technical assistance to countries working towards improving water productivity and conservation.[6]

The objectives of irrigation policy and reform include not only developing efficiency, but also maintaining equity and sustainability.[7] In addition, recent studies show that irrigation helps to decrease poverty.[8] Accordingly, another goal of irrigation reform is the reduction of malnutrition and poverty, and the increase of food security for poor farmers in developing countries.[9]

A. NATURE OF IRRIGATED LAND

Irrigation water comes from five different sources: (1) rainwater

---

3. STEPHEN MERRETT, WATER FOR AGRICULTURE: IRRIGATION ECONOMICS IN INTERNATIONAL PERSPECTIVE 1 (Taylor & Francis 2002).

4. *Id.* at 3.

5. Int'l. Water Mgmt. Inst., *available at* http://www.iwmi.cgiar.org/About_IWMI/Overview.aspx.

6. *See* The World Bank, *available at* http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/0,,pagePK:50004410~piPK:36602~theSitePK:29708,00.html.

7. ROGER D. NORTON, AGRICULTURAL DEVELOPMENT POLICY 203 (John Wiley & Sons, Ltd. 2004).

8. Intizar Hussain & Munir A. Hanjra, *Irrigation and Poverty Alleviation: Review of the Empirical Evidence,* 53 IRRIGATION AND DRAINAGE 1, 13 (2004), http://www.iwmi.cgiar.org/propoor/files/ADB_Project/Research_Papers/Irrigation_and_poverty_alleviation.pdf.

9. *See* Ian Carruthers, Mark W. Rosegrant & David Seckler, *Irrigation and Food Security in the 21st Century,* 11 IRRIGATION AND DRAINAGE SYSTEMS 83, 92, 99, 100 (1997).

collected prior to run-off into the watercourse; (2) diversion of surface water via canals, pumps, and the natural rise of a river; (3) water pumped from aquifers and springs; (4) reuse of urban or household wastewater; and (5) reuse of irrigation water.[10] In addition, agricultural land falls under four categories: "rain-fed, irrigation only, drainage only, and irrigation and drainage."[11] Freshwater is typically separated into two categories: (1) "blue water," which refers to water from rivers, lakes, and aquifers; and (2) "green water," which includes rainwater and soil moisture.[12] Regions that rely heavily on irrigation typically do not receive enough rainfall to sustain productive agriculture.[13] In these arid climates, irrigated land is generally located downstream of a watercourse, where river discharge is largest.[14]

B. TYPES OF IRRIGATION EQUIPMENT

Various methods exist for delivering irrigation water to agricultural land in regions where rainfall is an inadequate water source for growing crops. Most water delivery methods fall under one of three irrigation types: surface, subsurface, or localized.[15] "Surface" irrigation employs various delivery methods that rely on gravity.[16] In regions where farmland is concentrated near a watercourse, canal irrigation provides a system of manmade channels that allow farmers to control and coordinate their water diversions.[17] Farmers often use surface irrigation for row crops, such as cotton or corn, allowing for the containment of irrigation water in channels between rows.[18] Irrigation of paddy fields is similar to many other methods of surface irrigation, allowing farmers to flood their fields with large amounts of water.[19] "Subsurface" irrigation is a method of water delivery that controls water

---

10. MERRETT, *supra* note 3, at 6.

11. *Id.* at 19.

12. *The Challenges of Integrated River Basin Management in India*, 3 WATER POLICY BRIEFING 1, 5 (2002), http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/wpb03.pdf [hereinafter *The Challenges of Integrated River Basin Management in India*].

13. *See* Wulf E. Klohn & Bo G. Applegren, *Challenges in the Field of Water Resource Management in Agriculture*, SUSTAINABLE MANAGEMENT OF WATER IN AGRICULTURE 31, 38 (OECD 1998).

14. JACOB W. KIJNE, UNLOCKING THE WATER POTENTIAL OF AGRICULTURE 9 (FAO 2003), ftp://ftp.fao.org/agl/aglw/docs/unlocking_e.pdf.

15. FOOD AND AGRICULTURE ORGANIZATION OF THE U.N., CROPS AND DROPS: MAKING THE BEST USE OF WATER FOR AGRICULTURE 16-17 (FAO 2002), ftp://ftp.fao.org/docrep/fao/005/y3918e/y3918e00.pdf.

16. C.M. BURT ET AL., SELECTION OF IRRIGATION METHODS FOR AGRICULTURE 27 (American Society of Civil Engineers 2000).

17. *See* NEV. DIV. OF WATER PLANNING, WATER WORDS DICTIONARY 42 http://water.nv.gov/WaterPlanning/dict-1/ww-dictionary.pdf.

18. BURT ET AL., *supra* note 16, at 29.

19. *See* D. Renaulta & T. Facon, *Beyond Drops for Crops: A System Approach for Assessing the Values of Water in Rice-based Systems*, U.N. Food & Agriculture Organization Regional Office for Asia and the Pacific 8 (Feb. 12, 2004), http://www.fao.org/rice2004/en/pdf/renault.pdf.

table levels and delivers water directly to the root zone of the crop.[20] "Localized" irrigation, often referred to as micro-irrigation, includes any form of delivery method that delivers water directly to the plant, in frequent and small quantities.[21] Sprinklers can deliver water to crops via spray lines with nozzles driven by water pressure, conventional rotating sprinklers, mobile sprinkler lines, travelling rainguns that irrigate continuously, traveling booms that spray either upwards or downwards, and center-pivot and linear irrigators with drop nozzles.[22] Drip irrigation is another method of localized delivery that typically employs a system of tubes and hoses to provide continuous water to crops from just above, at, or below the soil surface.[23]

The method of water delivery can have a significant impact on water and crop productivity. Accordingly, investment in new water delivery technology is an important factor in the implementation of irrigation reform policies, as confirmed in the individual regional case studies discussed in the following sections of this article. Certain irrigation methods are more appropriate for some crops than others; also geographic, economic, and hydrologic limitations dictate the success of different methods of irrigation in different areas. For example, hillside farmers may be able to reduce energy costs by taking advantage of gravity flow, but economic conditions may limit investments in irrigation infrastructure. General knowledge of irrigation methods, along with scientific research, allows irrigators to better understand how to match the right irrigation system with their crops, geography, financial resources, and climate.

C. CROP REQUIREMENTS AND IRRIGATED CROP MANAGEMENT

The implementation of an effective irrigation policy inevitably relies heavily on the particular crops grown. Different crops have varying economic values, water requirements, and climate requirements. For instance, fruits and vegetables tend to be categorized as high value crops due to their higher input costs including pest control, labor, and water.[24] These input costs may drive more farmers to grow low-value crops such as cereals and rice.[25] The effect of input costs on a farmer's return, based on irrigation water use, is an important factor in calculating water productivity. Different types of crops often require different amounts of water during different periods of growth. Farmers generally design their agricultural operation to grow "dry crops," or those that do not require as much water, during the drier season, and

20. Daniel Hillel, *Small-scale Irrigation for Arid Zones: Principles and Options*, U.N. Food & Agriculture Organization [FAO], Natural Res. Mgmt. & Env't. Dept. ch. 4 p. 2 (1997) *available at* http://www.fao.org/docrep/W3094E/W3094E00.htm.

21. LARRY STRAND, INTEGRATED PEST MANAGEMENT FOR ALMONDS 19 (2d ed., UC IPM 2002).

22. ROGER BAILEY, IRRIGATED CROPS AND THEIR MANAGEMENT 42-43 (Farming Press 1990).

23. C. Wilson & N. Bauer, *Drip Irrigation for Home Gardens*, COLORADO STATE UNIVERSITY EXTENSION, Nov. 2005, http://www.ext.colostate.edu/PUBS/Garden/04702.html.

24. *See* BAILEY, *supra* note 22, at 25.

25. *Id.* at 112-13.

"wet crops" during the rainy season when possible.[26]

It is important to consider how a certain crop will respond to irrigation to attain maximum irrigation efficiency. Cereals such as winter wheat, winter barley, spring barley, rye, and oats are deep rooting crops, and if grown in soil with a high available water capacity, irrigation is unlikely to significantly increase their production.[27] Therefore, a rural river basin with irrigated agriculture could increase efficiency by reserving more water for crops that may have a better yield response to irrigation. Alternatively, vegetables are typically shallow-rooting crops and often suffer more than cereals in times of water shortage.[28] In addition to higher crop yields, farmers also benefit from having ample irrigation water throughout the growing season.[29] This benefit allows for proper plant establishment, continuous supply of products to market, control of product size, and quality of product.[30] Such benefits from reliable irrigation would likely spur farmers to demand assurance that irrigation water will be available throughout the growing season.[31] Fruit-growers must consider not only how water shortage might affect the quantity and quality of their fruit during the current growing season, but also how a water shortage could stunt the growth of perennial fruit producing plants and affect growth in future years.[32] Irrigated grassland can experience growth variation in response to water shortage, from year to year, and also during the growing season.[33]

Most farmers, with either commercial or subsistence operations, will eventually reach a point where they have to choose which crops to irrigate. For some, this decision will be made on a regular basis; for others, it will only be in particularly dry years.[34] These decisions play an important role in the efficiency of irrigation water; therefore, it is critical that farmers understand the economics of their crops and how to use their water resources to maximize productivity.

For many agriculturalists around the globe, especially those living in regions suffering from water shortages, irrigation crop management is critical to their profitability. These growers do not recklessly apply water to their crops, and likewise, they do not merely apply less water in times of dry spells or drought. Because applying too little water can result in profits failing to materialize, and applying too much water leaches nutrients out of the soil and can increase cost so much as to illuminate returns, the window of profitable water application is often quite narrow.[35] Planning is a necessity in irrigation practices, and it

26. MERRETT, *supra* note 3, at 19.
27. BAILEY, *supra* note 22, at 112-13.
28. *Id.* at 125.
29. *Id.*
30. *Id.*
31. *See Id.*
32. *Id.* at 146.
33. *See id.* at 165.
34. *Id.* at 180.
35. *Id.* at 1.

involves identifying situations where irrigation is financially and economically beneficial.[36] In order to implement efficient irrigation practices, irrigators must consider factors such as: the rate at which their crop removes water from the soil, field capacity, crop wilting points, root zone capacities, effects of soil texture on available water, and growth stages.[37] For purposes of this article, it is unnecessary to engage in an explanation of each of these factors. It is, however, imperative that irrigators understand the importance of the soil-plant-water relationship of their irrigated agriculture and the best management thereof.[38]

II. IRRIGATION WATER POLICY - INTERNATIONAL CASE STUDIES

The following case studies discuss seven different regions that have taken various approaches to irrigation reform: Australia, the Philippines, China, India, Egypt, Latin America, and the United States.

A. AUSTRALIA

Australia presents a unique situation in the international scheme of irrigation because agricultural water use has no direct impact on transboundary water systems.[39] Even though Australia does not directly share its water resources, it can indirectly affect the resources of any country that participates in global agricultural.[40]

Most water policy development in Australia focuses on the Murray-Darling river system, a basin that supports approximately 70% of Australia's irrigated agriculture.[41] The region's most significant crop is rice, followed by winter cropping, and horticulture.[42]

Irrigation system development in New South Wales ("NSW") began in 1933 and continued until 1964.[43] At that time, gravity-powered channels provided water to the vast region in order to "droughtproof" agriculture; also at that time, the government implemented state-based restrictions on certain crops during times of drought.[44]

By the early 1980s, local irrigators were concerned that the government was not sending an adequate portion of the collected revenue back to the region and was neglecting local maintenance of

36. *Id.* at 1-2.

37. *See id.* at 4, 13, 22, 24.

38. *See id.* at 2.

39. *See* Lin Crase, *An Introduction to Australian Water Policy, in* WATER POLICY IN AUSTRALIA: THE IMPACT OF CHANGE AND UNCERTAINTY 3 (Lin Crase ed., RFF Press 2008); Rebecca Letcher & Susan Powell, *The Hydrological Setting, in* WATER POLICY IN AUSTRALIA: THE IMPACT OF CHANGE AND UNCERTAINTY 17 (Lin Crase ed., RFF Press 2008).

40. *See* Food Trade discussion *infra* pp.35-36.

41. Jenny McLeod & George Warne, *Coping with the Reforms to Irrigated Agriculture: The Case of Murray Irrigation, in* WATER POLICY IN AUSTRALIA: THE IMPACT OF CHANGE AND UNCERTAINTY 90, 90 (Lin Crase ed., 2008).

42. *Id.* at 91.

43. *Id.* at 93.

44. *Id.* at 93 (stating restrictions include prohibiting irrigated permanent plantings of horticulture crops and bans on rice crops).

irrigation systems because the government head was remotely located in Sydney.[45] At that time, the irrigation infrastructure was aging and needed replacement, and salinization had deteriorated the quality of agricultural land.[46] Seeing an opportunity to improve financial and operational efficiency through a privatization process, Australia shifted its economic policy from one of "protectionism and subsidization" to a policy centered on "openness and economic rationalism."[47] Such privatization required the development of new administrative organizations, including the creation of Murray Irrigation Limited, an unlisted public company.[48] The company's legal status subjected it to trade regulation and taxation, and called for the irrigators on the system to be the exclusive shareholders.[49] The NSW state government maintained an integral role in the operation of Murray Irrigation Limited through the licensing system even though the company was privately owned.[50] The state government granted Murray Irrigation Limited a bulk license for 1,450,000 megaliters of water from the Murray River system to deliver water to shareholders.[51] The license agreement included Murray Irrigation Limited's obligation to reasonably manage the river basin environment and the effect on downstream users.[52]

The irrigator-driven privatization of this river system allowed for an increase in water supply efficiency. Murray Irrigation Limited implemented new technology such as radio control of supply channels.[53] In exchange for returning unused water to the NSW government, Murray Irrigation Limited receives state funding for infrastructure investment, further increasing water supply efficiency.[54] Murray Irrigation Limited charges irrigators who use the system annual fees, which not only cover operational costs, but also allow for a reserve, saving for years when water sales are low.[55] In addition, as part of separation agreements, the company receives funding from the NSW government for certain maintenance projects, although the government subjects the company to strict guidelines for approval.[56]

Australia's community of irrigated agriculture has realized substantial benefits since the privatization of the Murray River irrigation system including, but not limited to: (1) significant

45. *Id.* at 94.

46. THE WORLD BANK AGRIC. AND RURAL DEV., SHAPING THE FUTURE OF WATER FOR AGRICULTURE: A SOURCEBOOK FOR INVESTMENT IN AGRICULTURAL WATER MANAGEMENT 93 (The World Bank et al. eds., 2005) [hereinafter SHAPING THE FUTURE OF WATER FOR AGRICULTURE].

47. *Id.*; *See also* McLeod, *supra* note 41, at 94.

48. McLeod, *supra* note 41, at 94.

49. *Id.* at 95.

50. *Id.*

51. *Id.*

52. *Id.*

53. *Id.*

54. *Id.* at 97.

55. *Id.*

56. *Id.* at 98.

developments of technical efficiencies; (2) environmental achievements; (3) great assistance in times of water shortages; and (4) increased ability to assist shareholders and represent their interests to all levels of government.[57] In recent years, the Council of Australian Governments entered into agreements that reflect the direction of future reform, including the promotion of water trading, the introduction of environmental allocations, and the integration of natural resource management.[58]

B. PHILIPPINES

Political tension has long been an obstacle for irrigation reform in the Philippines because a lack of cooperation from stakeholders, who were working to protect their own assets, has hindered numerous well-intentioned reforms.[59] In May 1963, the legislature passed a bill creating the National Irrigation Administration ("NIA"), whose duties included studying, investigating, improving, and administering all national irrigation systems.[60] The NIA did not, however, truly begin to expand until the 1965 election of Ferdinand Marcos, whose campaign slogan was "Irrigation is the crying need of the hour!"[61] NIA collected massive amounts of foreign capital from the World Bank and the Asian Development Bank, and under Marcos's authoritarian administration, the NIA grew into "the finest irrigation agency in . . . any developing country in the World."[62]

In 1983, World Bank recommended that the NIA concentrate more on rehabilitation and small-scale projects and downsize its ambitious goals.[63] The World Bank's lending reflected this recommendation, and as a result, NIA began to falter.[64] Irrigation reform became highly politicized by this time. Marcos was a perceptive politician, and he knew how to appease his rural constituency; his political platform based on rice self-sufficiency prevented Filipinos from going hungry and kept him in power.[65] A change of power in the 1980s brought a more democratic government, and with it came attempts to decentralize irrigation management.[66] Irrigation associations entered into fee collection contracts and canal maintenance contracts with NIA.[67]

57. *Id.* at 106.

58. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 94.

59. Thomas Panella, *Irrigation Development and Management Reform in the Philippines: Stakeholder Interests and Implementation, in* THE POLITICS OF IRRIGATION REFORM 95, 95 (Peter P. Mollinga & Alex Bolding eds., 2004).

60. *Id.* at 97-98.

61. *Id.* at 98.

62. *See id.* at 99-102.

63. *Id.*

64. *See id.* at 114.

65. *Id.* at 104.

66. *Id.* at 113.

67. Joost Oorthuizen, *The Politics of Irrigation Policy Implementation: Networks of Votes, Bribes and Coca-Cola in the Philippines, in* THE POLITICS OF IRRIGATION REFORM 263, 273 (Peter P. Mollinga & Alex Bolding eds., 2004).

However, the interests of lenders and borrowers did not align, which created largely unsuccessful communal irrigation systems.[68] Politicians used their power and threatened violence in order to maintain control of the water, and largely disregarded the NIA's participation.[69] The ensuing cycle of unsuccessful reforms is too lengthy for the purposes of this study.

C. CHINA

China receives an average annual rainfall of 600-700 mm,[70] most of which occurs over a two-month period in the summer. The amount varies from up to 2,000 mm in the southern region, to as little as 400 mm in the northern region.[71] Irrigation is critical to China's agriculture industry because of this irregularity in rainfall.[72] Additionally, agriculture in China must compete for water against a rapidly growing industrial sector and a large population requiring extensive municipal use.[73]

China experienced a major expansion of irrigation between 1953 and 1980, when its irrigated area increased from 16 million to 45 million hectares of agricultural land.[74] Since the 1950s, the Chinese government has invested over 100 billion U.S. dollars in new infrastructure.[75] Before the 1970s, the farming community considered water to be abundant, and as a result of the complete lack of pricing, there was no incentive to save water.[76]

China experienced a period of decollectivization during the 1970s and 1980s, which led to quick growth in agricultural production and productivity, but also created ambiguous property rights over most local water delivery systems.[77] While water storage and delivery infrastructure are critical aspects of China's water resource management, uncertainty over water rights has resulted in very little motivation to maintain them.[78] As irrigated land has decreased and food prices have increased, officials have focused more attention on agricultural water reform, shifting from the development of new

68. Panella, *supra* note 59, at 113.
69. Oorthuizen, *supra* note 67, at 273.
70. Ramaswamy R. Iyer, K. V. Raju & Jinxia Wang, *Policy and Institutional Reforms in the Water Sector: Experiences and Lessons from China and India*, *in* THE DRAGON & THE ELEPHANT: AGRICULTURAL AND RURAL REFORMS IN CHINA AND INDIA 180, 180 (Ashok Gulati & Shenggen Fan eds., 2007).
71. *Id.*
72. *Id.*
73. Bryan Lohmar et al., *China's Agricultural Water Policy Reforms: Increasing Investment, Resolving Conflicts, and Revising Incentives*, AGRIC. INFO. BULLETIN NO. 782 (U.S. Dep't of Agric.), Mar. 2003, at 1.
74. Iyer et al., *supra* note 70, at 181.
75. *Id.* at 182.
76. Lohmar et al., *supra* note 73, at 17.
77. Iyer et al., *supra* note 70, at 183-84.
78. *Id.*

projects to the maintenance of existing infrastructure.[79]

Over the past 50 years, China has developed an extensive bureaucratic system to manage its water resources, led by the State Council and executed primarily by the Ministry of Water Resources, followed by a complex vertical and horizontal structure of controlling authorities.[80] In more recent years, this bureaucracy has focused on resolving conflicts between agricultural and industrial users, particularly in regions where there has been a significant reallocation of water from agricultural to industrial and municipal uses.[81]

While the government has attempted to promote water-saving technologies and has considered the use of a water pricing strategy, efforts to use more sophisticated water delivery methods have generally failed, as political pressure has prevented the implementation of an aggressive pricing strategy.[82] While prices have increased over the years, they are still considerably low, and although price increases may encourage water conservation, the Chinese government is unwilling to substantially raise prices, as that will lower farmers' income, and raising the income of farmers remains an important policy goal.[83]

D. INDIA

Most of India's rainfall occurs within a few week period of intense precipitation that ranges from less than 200 mm in areas of Rajasthan to 11,000 mm in the northeastern part of the country.[84] Consequently, since medieval times, India's irrigation practices centered around village-owned tanks or pools that collected water during times of heavy rain to sustain life through the rest of the year.[85] These tanks stored water that was crucial for irrigated crops, provided protection against drought, and served multiple uses for the community providing water for domestic uses, livestock, and wildlife.[86] Additionally, these water harvesting structures helped by "preventing soil erosion and damaging floods caused by violent, unchecked water flows."[87] Because they provided many benefits, and because people relied heavily on them, kings, religious leaders, and philanthropists built numerous tanks scattered all over their territories.[88]

Beginning in the 1950s, land reforms negatively affected the tanks,

---

79. *Id.* at 184.
80. Lohmar et al., *supra* note 73, at 5.
81. *See Id.* at 5-8.
82. *Id.*
83. Lohmar et al., *supra* note 73, at v.
84. Iyer et al., *supra* note 70, at 188-189.
85. *Id.* at 190.
86. *Id.*
87. *See Rethinking Tank Rehabilitation: Issues in Restoring Old Tanks to Their Original State in Irrigation Structure*, WATER POLICY BRIEFING (Int'l Water Mgmt. Inst., Gujarat, India), 2 (2003), http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/wpb07.pdf [hereinafter *Rethinking*].
88. Iyer et al., *supra* note 70, at 190.

and India saw a decrease in tank-irrigated agricultural land.[89] However, in 1947, when India gained its independence,[90] the government began an ambitious program to improve agricultural production through a well-managed and extensive irrigation infrastructure, and, over the course of eight separate five-year plans, introduced over 1,200 projects.[91]

Since the 1970s, Indian policy has focused on irrigation reform and recruiting more farmer participation in irrigation management;[92] however, progress has been slow, and reform has yet to address the exclusive governmental control of allocation of irrigation water.[93] In 1997, a group of water professionals set up an organization called *Sahayoga*, or "work together," and held meetings to encourage farmers to take action and participate in the management of irrigation systems.[94] Several water user associations formed under the authority of the water professionals, however by 2002, the farmers wanted their own organizations and they formed *Pragathi*, or the "Farmer's Society for Rural Studies and Development".[95] Today, farmers in tank communities remain involved in the cleaning and deepening of tanks before the monsoon season, recognizing the importance of effective maintenance.[96]

In recent years, a prominent concern for India is the condition of tanks that are between fifty and one hundred years old and are located all over the country.[97] Classical tank rehabilitation is a costly process of desilting the tank bed, repairing outlets, and lining canals, which returns few advantages to farmers.[98] Experts suggest that modernization, rather than rehabilitation, would be more practical than using resources to restore out-dated systems to their former conditions.[99]

While some experts predict imminent crisis in India, as water management and balancing supply and demand is such a fragile exercise, the Center for Science and Environment maintains that "proper water management and extensive community-based water harvesting would preclude any crisis."[100] Tank rehabilitation and modernization projects require farmer participation and Integrated River Basin Management ("IRBM").[101] India, after looking to countries that have developed an effective IRBM system, attempted to adopt the United States' Tennessee Valley River Authority model, which unfortunately,

89. *Id.*
90. CENTRAL INTELLIGENCE AGENCY, THE WORLD FACTBOOK 261 (2006).
91. Iyer et al., *supra* note 70, at 190-191.
92. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 96.
93. *Id.*
94. *Id.*
95. *Id.*
96. *The Challenges of Integrated River Basin Management in India, supra* note 12, at 2.
97. *Rethinking, supra* note 87, at 1.
98. *Id.*
99. *Id.* at 3-4.
100. Iyer et al., *supra* note 70, at 189-190.
101. *See* The *Challenges of Integrated River Basin Management in India, supra* note 12, at 1.

proved to be a failure.[102] Despite this and other examples of less-than-successful attempts at IRBM, basin-level management is still the best option; however, India will likely continue to implement participatory programs.[103]

E. EGYPT

Even though cultivable land in Egypt is concentrated within a narrow strip along the Nile River where there is ample water for irrigation, "agriculture... provides more than a third of [the] nation['s] employment."[104] In addition, almost two-thirds of the nation's poor rely on agriculture for their livelihood.[105] Along the Nile River, excess water, rather than water scarcity, is the pressing issue.

In areas with excess water due to over-irrigation or rainfall, farmland becomes water logged, and the salinity of the soil can increase, causing a loss of water efficiency and crop productivity.[106] Drainage systems on farms collect excess water and transport it to a main system where it can drain into a major watercourse, such as a river or lake.[107] Collecting excess water from the surface of the land and collecting excess subsurface water controls the water table and allows for aeration of the root zone, which improves crop growth.[108]

"After the completion of the Aswan High Dam, the Government of Egypt developed irrigation infrastructure along the Nile River."[109] The increase in year-round irrigation activity led to water logging and salinity increases, which ultimately hurt agricultural production in the basin.[110] Egypt began developing drainage projects in 1970, and the World Bank supported several of the government's projects concentrating on the Nile Delta.[111] In recent years, Egypt's National Drainage Projects I and II have built on the efforts of these earlier projects.[112]

The National Drainage Project I began in 1992 and its design increased both agricultural productivity through the extraction of excess water and the control of rising water tables in the Nile River

102. *Id.* at 1.
103. *See id.* at 1, 6.
104. *Increasing Agricultural Productivity through Improved Drainage: Egypt's National Drainage Projects I and II*, 22 WATER FEATURE STORIES (Water Sector Bd., The World Bank), 1 (2008), http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2008/10/30/000333037_20081030233323/Rendered/PDF/462350BRI0box310issue0no0FS221Egypt.pdf [hereinafter *Increasing Agricultural Productivity*].
105. *Id.*
106. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 176-77.
107. *Id.* at 176.
108. *See id.*
109. *Increasing Agricultural Productivity*, *supra* note 104, at 1.
110. *Id.*
111. *Id.*
112. *Id.*

Delta.[113] The project focused on the installation of state-of-the-art drainage networks, methods of management, quality control for maintenance, and cost recovery of the systems.[114] The project successfully increased agricultural productivity on 312,000 hectares, improved infrastructure, and successfully covered investment costs.[115] Many farmers were able to switch to higher-value crops as the Nile Delta reached one of the highest water efficiency rates in the world.[116] The National Drainage Project II ("Project II") began in 2001, and its goal is to expand on the first installment, by increasing productivity on an additional 336,000 hectares and addressing environmental issues relating to the discharge of untreated waste into the drains.[117] Project II is not yet complete; however, the government and farmers have demonstrated their strong dedication to adopting the new irrigation technologies and a well-functioning system of cost recovery.[118]

While the irrigation problems faced by Egypt along the Nile River are vastly different from regions that suffer from severe water scarcity, the underlying issue is the same: increasing water productivity. Like over-irrigating crops, leaving excess water in the water table prevents putting the water to its most productive use: irrigation. Implementing drainage systems results in large volumes of water becoming available for more productive uses. Reuse of drainage water saves freshwater resources and has been a national policy of Egypt since the 1980s, and remains a top priority on the agenda of Egypt's Drainage Research Institute.[119]

F. LATIN AMERICA

Irrigation in Latin America stretches across diverse climate zones, from arid regions to tropical coastal plains, and supports crops ranging from tropical fruit to rice.[120] In addition to climatic and geographic diversity, Latin America has a rich cultural diversity that provides several unique examples of irrigation policy and reform. Three such examples are Chile, Brazil, and Guatemala.

In Chile, the current water code allows for two closely related water markets to operate in the Limarí Basin.[121] The first is a "spot market" allowing volumetric water trades,[122] and the second is a permanent

113. *Increasing Agricultural Productivity, supra* note 104, at 1; *see also* SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 194.

114. *Increasing Agricultural Productivity, supra* note 104, at 1.

115. *Id.* at 1-2.

116. *Id.* at 1.

117. *Id.* at 2.

118. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 176-77.

119. *Id.* at 182.

120. Fernando J. Gonzales & Salman M.A. Salman, *Institutional Reform for Irrigation and Drainage: Proceedings of a World Bank Workshop* 149 (World Bank, Technical Paper No. 524, 2002).

121. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 83.

122. *Id.*

transaction market for transactions involving water rights.[123] World Bank data from 2000 showed that a significant percentage of allocated water, as much as 21% during one dry season, was reallocated in the spot market during the previous years.[124] The permanent market facilitates the trade of water rights over time.[125] Between 1981 and 2000 over 27% of all water rights were traded separately from land transfers.[126] The two separate, but related, markets allow for a more dynamic system of water allocation. The system in Chile supports the hypothesis that effective legislation allowing private water transactions can be an active instrument for efficient allocation of water among irrigators.[127]

In Brazil, prior to 1992, the irrigation system was in a state of disorder and lawlessness.[128] The government did not limit the volume or timing of irrigators' diversions or storage of water from rivers that only flow during the rainy season.[129] This resulted in those individuals upstream receiving most, if not all, of the water.[130] Responding to increased pressure from the industrial and tourism sectors to stabilize the water supply, the legislature formed the Secretariat of Water Resources ("SWR").[131] With help from the World Bank, and an intensive study of water resource systems in the United States, the legislature developed a system of water law allowing for the issuance of water rights.[132] The initial water law was amended several times as the SWR expanded its knowledge and awareness of irrigation policy.[133]

In Guatemala, farmers who have no direct connection to a water supply are able to obtain their irrigation water from one of over 100 community-owned and operated irrigation systems.[134] Each farm has a tap that allows the farmer to access the community irrigation infrastructure.[135] On average, the systems cover twenty hectares, while the average farm size is only 0.2 hectares.[136] The systems are successful because sharing farmers cooperate with each other and form tightly knit groups.[137] Typically, farmers grow high-value crops and are able to pay off their government loans for construction of the irrigation systems in less than three years.[138]

123. *Id.*
124. *Id.*
125. *Id.*
126. *Id.*
127. *Id.*
128. *Id.* at 84.
129. *Id.*
130. *Id.*
131. *Id.*
132. *Id.*
133. *Id.*
134. *Id.* at 252.
135. *Id.*
136. *Id.*
137. *Id.*
138. *Id.*

G. THE UNITED STATES

Water policy and law in the United States has a constructive division at the 100th meridian, separating the western and eastern regions of the country.[139] While there is an average of forty inches of rainfall per year east of this dividing line, there is less than twenty inches west of the same point.[140] Irrigated land in the United States is very diverse, with some regions relying heavily on surface water for irrigation, others relying on groundwater, and some regions sustained by rainfall.[141] However, groundwater supplies approximately two-thirds of irrigated agriculture.[142] The largest proportion of this groundwater comes from the High Plains regional aquifer, which underlies six states and approximately 174,000 square miles, comprised mostly of the 134,000 square mile Ogallala aquifer.[143] Western states generally follow the prior appropriation doctrine of water law and have a system of water rights allocation based on beneficial use.[144]

Between the 1920s and the 1970s in the American West, the United States Army Corps of Engineers ("the Corps") and Bureau of Reclamation ("the Bureau") undertook several dam building projects that led to the development of irrigation programs.[145] The first beneficiaries of these irrigation programs were Mormon families, who were settling down and looking for a place of their own.[146] The Corps and the Bureau subsidized these small farms, whose irrigation projects received federal financing with interest free loans.[147] Farming expanded and became an activity not just for families, but also for large corporations, such as Exxon and Prudential Insurance Company, as the agribusiness sector began to grow significantly.[148] The Roosevelt-Truman administration implemented massive dam and irrigation programs with great enthusiasm, but with little mention of cost-benefit analyses.[149] In *Cadillac Desert: The American West and its Disappearing Water*, Marc Reisner provides acute insight into how the American government tried to carve out farmsteads cheaply for Americans by "letting them try to scratch a living out of them [and] develop the nation's resources and build up its character," resulting in a poor

---

139. A. DAN TARLOCK, JAMES N. CORBRIDGE, JR., & DAVID H. GETCHES, WATER RESOURCE MANAGEMENT: A CASEBOOK IN LAW AND PUBLIC POLICY 17 (5th ed. 2002).

140. *Id.*

141. *See* United States Geological Survey, *Irrigation water use*, May 13, 2009, http://ga.water.usgs.gov/edu/wuir.html.

142. Talah S. Arabiyat, Eduardo Segarra, & David B. Willis, *Sophisticated Irrigation Technology and Biotechnology Adoption: Impacts on Ground Water Conservation*, 2 J. AGROBIOTECHNOLOGY MGMT. & ECON., 132, 132 (1999); *See also* TARLOCK ET AL., *supra* note 139, at 20.

143. TARLOCK ET AL., *supra* note 139, at 20 (noting the six states include Nebraska, Colorado, Kansas, New Mexico, Texas, and Oklahoma).

144. *Id.* at 159-160.

145. *See* MERRETT, *supra* note 3, at 142.

146. *Id.* at 143.

147. *Id.*

148. *Id.*

149. *Id.* at 145.

economic outcome and water scarcity.[150]

Today, companies in the water-scarce western United States provide much of the research for developing new technology and biotechnology. Bayer Crop Science ("Bayer") is an agrochemical and biotechnology research company dedicated to providing innovative products for the agricultural sector, with an emphasis in water conservation and protection.[151] Bayer develops drought resistant crops and weed management tools that lessen competition for water.[152] Texas Tech University in Lubbock, Texas recently installed a new, state-of-the-art subsurface drip irrigation system on the Quaker Research Farm, which addresses issues of water conservation and drought resistant farming.[153]

The American West is the home of developing water conservation policy. With such a large percentage of all irrigation water coming from groundwater, a major concern is aquifer-saturated thickness, particularly in the Ogallala Aquifer region, where saturated thickness is decreasing due to overdraft.[154] The Panhandle Groundwater Conservation District ("the District") in Texas has implemented a policy known as "50/50," under which 50% of the current saturated thickness must remain fifty years from 2008, the date of its implementation.[155] The policy's design provides a benchmark and develops a tracking system to review changes in the saturated thickness of the water table, while adjusting water allocation to achieve periodic goals.[156] The District's goals include the following: developing strategies for efficient groundwater use; preventing waste; planning for drought conditions; and managing conjunctive surface water.[157]

III. SOLUTIONS FOR INCREASING IRRIGATION EFFICIENCY

Agriculture today faces a sizeable challenge to improve efficiency as the world population grows and the demand for food increases. In addition to rising populations, average life expectancies are increasing and developing countries are experiencing changes in lifestyles and food consumption patterns, putting even more pressure on the agricultural sector to increase crop and water productivity and irrigation

150. MARC REISNER, CADILLAC DESERT: THE AMERICAN WEST AND ITS DISAPPEARING WATER 43 (1986).

151. *See* Bayer CropScience, *Water Conservation and Protection*, http://www.bayercropscience.com/bcsweb/cropprotection.nsf/id/WaterConservation (last visited Oct. 9, 2009).

152. *Id.*

153. *See* Texas Tech University College of Agricultural Sciences & Natural Resources, *Quaker Research Farm Adds High-Tech Irrigation System*, http://www.depts.ttu.edu/agriculturalsciences/news/?p=289 (last visited Oct. 9, 2009).

154. Arabiyat et al., *supra* note 142, at 132.

155. *See* PANHANDLE GROUNDWATER CONSERVATION DISTRICT, PANHANDLE GROUNDWATER CONSERVATION DISTRICT MANAGEMENT PLAN 30 (Aug. 20, 2008), http://www.pgcd.us/rules/Management%20Plan%208-20-08%20Final.pdf.

156. *Id.*

157. *Id.* at 30-38.

efficiency.[158]

True efficiency, with regard to irrigation, refers to more than the amount of water delivered to the rootzone of the crop.[159] There are many other factors that play roles in achieving efficiency: timing of the rainy season and planting season; inputs such as fertilizer; and the manner in which water stress affects crops at various stages of growth.[160] Water productivity, technology, and effective management allow irrigators to maintain control over the water supply and deliver water to crops exactly where and when necessary in order to achieve maximum efficiency.[161]

A. WATER PRODUCTIVITY

Water productivity is a measure of efficiency that refers to the net economic, environmental, and societal benefits water use practices can achieve.[162] Water productivity falls into two categories: physical water productivity and economic water productivity.[163] The former focuses on the "more crop per drop" concept and evaluates the amount of output produced per unit of water use,[164] while economic water productivity calculates the economic benefit from each unit of water use.[165]

There are several points along a water delivery system or irrigation system where water productivity can improve. Nearly all irrigation systems lose water through evaporation, or water that never reaches the crop.[166] Water is also lost through the process of transpiration, where plants convert water into water vapor, as more biomass requires more transpiration.[167] During the delivery process, many irrigation systems experience a certain amount of drainage flow, which often results in a loss of water productivity, but also provides a benefit to downstream farmers.[168] In addition, farm-level, basin-level, regional, and national policies and practices all play a part in maintaining the maximum productivity of an entire irrigation system.

1. On-farm productivity and irrigation efficiency

Several factors affect the maximization of on-farm irrigation

158. Alfons Weersink et al., *The World Food Crisis: Causes and the Implications for Ontario Agriculture* 14-15 (Dep't of Food, Agric. & Resource Econ., Univ. of Guelph, Working Paper, 2008), http://ageconsearch.umn.edu/bitstream/46503/2/Food%20Report%20Aug%2008.pdf.

159. *See* MERRETT, *supra* note 3, at 20.

160. *Id.*

161. *See id.*

162. WATER FOR FOOD, WATER FOR LIFE: A COMPREHENSIVE ASSESSMENT OF WATER MANAGEMENT IN AGRICULTURE 281 (David Molden ed., 2007).

163. *Id.* at 282.

164. *Id.*

165. *Id.*

166. *See id.*

167. *Id.* at 286, 287.

168. *See id.* at 289.

efficiency, including the following: (1) accurate crop water requirement information for establishing an effective irrigation schedule;[169] (2) a fine-tuned irrigation system suitable for achieving the highest possible irrigation water distribution uniformity;[170] and (3) an on-demand irrigation water supply capable of delivery at the necessary time and in the required quantity.[171]

The first factor requires that irrigators have timely access to accurate crop water-use information. Even basic knowledge of crop and climactic conditions in the area can allow a farmer to improve productivity, but many farmers have the added benefit of technologically advanced equipment that allows them to fine tune their irrigation practices and further increase productivity. In California, a comprehensive data information collection called CIMIS collects data from a network of over 130 computerized and automated weather stations utilizing temperature, humidity, wind speed, and solar radiation.[172] Not only do farmers use this system to manage their crop irrigation, but researchers also use it to develop new irrigation technologies.[173]

Distribution uniformity is the second essential factor for improving farm-level efficiency. When an irrigation system does not deliver water uniformly, there will be areas of the field that receive less water than others, and often these areas are systematically the same for each watering.[174] Farmers may use more water in order to adequately irrigate those areas, and as a result, will over-water other parts of the field.[175]

The final essential factor for improving farm-level efficiency is an on-demand water delivery system. This may be the most difficult to accomplish. Irrigation water in the agricultural setting is not always as readily available as turning on the faucet. From the author's experience, in the Rio Grande Valley in New Mexico, farmers must request water and often wait two or three days before they can begin irrigating, making sure that they do not interfere with their neighbors' irrigation. Often times, the irrigation water authority will tell a farmer he can irrigate on a certain day. The farmer will take the water when he can, regardless of soil moisture content, crop requirements, and previous or future rainfall, creating an inefficient irrigation practice.

While the above list of essential factors is not exhaustive, it provides a good starting point for achieving farm-level efficiency, and it happens to be the framework for California's implemented policy.[176] California's

---

169. Baryohay Davidoff, *Three Essential Elements of On-farm Irrigation Efficiency and Conservation*, *in* THE MANAGEMENT OF WATER QUALITY AND IRRIGATION TECHNOLOGIES 153, 158 (Jose Albiac & Ariel Dinar eds., 2009).

170. *Id.* at 158, 162.

171. *Id.* at 158.

172. *Id.* at 159.

173. *See id.* at 161-62.

174. *Id.* at 162-63.

175. *Id.* at 163.

176. *Id.* at 158.

experience has demonstrated that improving efficiency, conserving water, and eliminating waste is a very complex effort.[177]

2. Basin-Scale Efficiency

While increasing crop productivity occurs wholly at the farm level, there are a number of delivery, diversion, distribution, and reuse approaches that influence basin-level productivity.[178] Water distribution strategies can focus on these factors in order to reduce wasted outflows, reallocate water resource from low to high value crops, and provide means to recapture and reuse water, all in order to facilitate productive practices at the farm level.[179] Pollution of a water resource can also affect productivity, especially for those downstream of the source.[180] Basin-level management provides a way to better maintain water quality while considering the "big picture," rather than how individual irrigators impact water quality.[181]

Basin-level control also provides a means to maintain "common areas" of the water resource.[182] For example, an individual irrigator on a canal system can be responsible for his own irrigation system—ditches, turnouts, and borders—however, this does little for maintaining productivity of the basin as a whole if the main canals are not properly managed.[183] These main canals could be a source of inefficiency due to evaporation or poor maintenance.[184] Basin-level efficiency plays a large role in management of the water resource, and it allows for tradeoffs within the system that help develop a strategy based on cost and benefit.[185] Without some system of management or control, the common canals, tanks, or other delivery systems could fall by the wayside as irrigators only maintain their own systems. Basin-level management is discussed further in a following section of this article.

B. TECHNOLOGY

Water delivery technology has a significant impact on productivity. Many countries have implemented policies that focus on enhancing older irrigation systems with new technology, for example: lining ditches to reduce seepage, installing underground pipelines to reduce

177. *Id.* at 175.

178. INTERNATIONAL WATER MANAGEMENT INSTITUTE, WATER PRODUCTIVITY IN AGRICULTURE: LIMITS AND OPPORTUNITIES FOR IMPROVEMENT 10-11 (J.W. Kijne, R. Barker & D. Molden eds., 2003).

179. *Id.* at 11-12.

180. *Id.*

181. *See generally id.* at 12 (explaining how individual farmers make changes without considering the big picture).

182. *See generally id.* at 10-12 (explaining basin-level actions that allocate water to higher-value uses and promote reuse).

183. *See id.* at 13-14.

184. *See generally id.* (describing the relationship between farm and basin-level water management).

185. WATER FOR FOOD WATER FOR LIFE, *supra* note 162, at 300.

evaporation, and developing drainage systems to prevent salinization.[186]

Advancements in technology have resulted in increases in the harvest index and the ratio of biomass to transpiration for many widespread crops, such as wheat and rice.[187] Much of this advancement occurred between the 1960s and the 1980s, during the green revolution, and while many experts are skeptical that there is little more room for improvement, crop breeding still has potential for improving water productivity.[188] Crop breeding and crop science programs continue to provide drought, disease, pest, and salinity-resistant varieties of crops.[189] Such biotechnology can reduce the risk of crop failure; therefore, it can reduce the waste of water used on failed crops, which ultimately increases productivity.[190]

C. MANAGEMENT AND WATER INSTITUTIONS

Countries striving to improve agricultural water management schemes face several challenges, including developing "(1) the policy and institutional challenge, (2) the economic and financial challenge, (3) the problem of declining investment, (4) the challenge of technology and water resources to supply growing demand, (5) the poverty and rural incomes challenge, and (6) environmental dimensions and the sustainability imperative."[191]

Considering the World Bank's client countries, many have irrigation schemes that are primarily controlled by big government; thus, the control does not lie with local municipalities.[192] The governments treat irrigators as beneficiaries rather than participators, and often do not collect taxes or fees to cover all costs of maintaining the irrigation systems.[193] A vicious cycle begins when collected monies are insufficient for upkeep of the system, as farmers are then unwilling to pay fees for an inadequate system, which compounds the problem of insufficient funds.[194] As a result, many countries are shifting control of irrigation systems to the local or regional level to empower the water users, and to create more incentive for irrigators to maintain their systems.[195]

1. Participatory Irrigation Management

As previously mentioned, irrigated agriculture is the largest user of freshwater, and this use will continue to increase along with the world

186. *Id.* at 295.
187. *Id.* at 291, 296.
188. *Id.*
189. *Id.*
190. *See id.* at 291.
191. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 4.
192. Gonzalez & Salman, *supra* note 120, at 14.
193. *Id.*
194. *Id.*
195. *See* SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 71.

population and the demand for agricultural products.[196] Providing subsidies for water is a widely used practice, and as a result, irrigators commonly pay less than 10% of the operating costs to deliver water.[197] Many analysts approximate that overall water efficiency is around 40%, "meaning that more than half of all water diverted for agriculture never produces food."[198]

Many countries, via government programs or water management institutions, have implemented strategies to modernize old irrigation systems and increase the role that the private sector and stakeholders have in increasing efficiency.[199] Farmer participation is widely accepted as a successful and effective practice, as it recognizes that government policy makers do not necessarily know what is best for individual irrigators.[200] Water user associations ("WUAs"), or groups of farmers whose purpose is to manage the hydrological system or irrigation district in which they participate, take many forms and have varying levels of farmer control, but share the goal of achieving optimal utility from available resources.[201] The legal framework for establishing WUAs, and other similar institutions, typically consists of three basic legal requirements: an enabling law, bylaws, and a transfer agreement between an irrigation department and the WUA, which controls water matters at the state or province level.[202] For participatory irrigation management to function effectively, its legal framework should provide: (1) an effective alternative to resolve water conflicts; (2) assurances that the government will fulfill its obligations to the organization; and (3) an effective and transparent method for making decisions regarding future reform and management.[203]

Participatory irrigation management can be a challenge in countries where the government provides most services, or among cultures that view water as a God-given right that cannot be infringed upon.[204] Yet, several countries are beginning to implement participatory irrigation management.[205] It may be too early to judge the benefits or harms of such management, but in parts of India and arid parts of Turkey, reports indicate considerable water savings, which allows for water delivery to

---

196. Gonzalez & Salman, *supra* note 120, at 60.

197. *Id.*

198. *Id.*

199. *Id.*

200. Adam Chambers & Graham Trengrove, *The Implications of Informational Asymmetry for the Achievement of Australia's National Water Objectives*, A Contributed Paper Presented to the 53rd Annual Conference of the Australian Agricultural and Resource Economics Society (Feb. 11-13, 2009), *available at* http://ageconsearch.umn.edu/handle/47613.

201. Gonzalez & Salman, *supra* note 120, at 61.

202. *Id.* at 62.

203. K. William Easter & Slim Zekri, *Reform of Irrigation Management and Investment Policy in African Development* 8, Presented at the Pre-IAAE Conference on African Agricultural Economics (Aug. 13-14, 2003), *available at* http://ageconsearch.umn.edu/bitstream/14491/1/cp03ea01.pdf.

204. Gonzalez & Salman, *supra* note 120, at 62.

205. *See id.*

more farmers.[206] Both countries attribute the water savings to effective pricing strategies, and have realized a considerable reduction in government expenditures.[207]

The benefits of a participatory irrigation management can include better maintenance of irrigation systems, community organization that benefits other endeavors, and shifting the financial burden of establishing and maintaining such systems from the government to the irrigators.[208] Local farmers with knowledge and direct experience with irrigated agriculture are better situated to develop irrigation systems consistent with crop requirements, and are more suitable for achieving sustainability than governments are.

2. Governing Water Law

Countries establish WUAs through comprehensive water law, basic law, laws establishing cooperatives, or laws authorizing non-governmental entities. [209] Often times the law provides that the WUA must establish bylaws in order to operate as a legal entity.[210] The bylaws typically define the area that the WUA governs, which often matches the boundary of a hydrological unit.[211] They also establish enabling laws that characterize the relationship between the irrigation department and the WUA, as well as the duties and obligations of both.[212] The bylaws should also set rules for restricting membership in the WUA, usually limiting it to landowners, but often including tenants or subsequent owners.[213] As a legal entity, a WUA may also include in the bylaws the ability to contract with other parties, sue in its own name, obtain loans from private sources, and hold title to assets.[214] WUAs generally have executive bodies that deal with complaints and disputes, hold bank accounts, attend to administrative matters, set water charges, establish a system of water rotation, and train new members.[215]

Typically, the WUA will have an agreement with the state irrigation department that transfers all or part of its water management duties and responsibilities to the WUA.[216] Often times the irrigation department will transfer control over a certain bulk amount of water, and the WUA will have the task of apportioning that water among irrigators.[217]

206. *Id.* at 73.
207. *Id.*
208. *Id* at 60.
209. *See id.* at 63.
210. *Id.*
211. *Id.*
212. *Id.*
213. *Id.* at 64.
214. *Id.* at 65.
215. *Id.* at 66.
216. *Id.* at 70.
217. *Id.* at 71.

D. ECONOMIC INCENTIVES

Economic motivations such as tax incentives, subsidies, and water pricing can be useful tools for implementing water resource policy, which encourage farmers to adopt resource-conserving agricultural practices.[218] Typically, state governments provide and implement economic incentives.[219] However, the World Bank participates in the promotion of incentive packages designed to encourage water conservation.[220]

Providing incentives through tax deductions, tax exemptions, or tax credits allow policy makers to influence the behavior of irrigators by encouraging more efficient water use practices.[221] However, governments can also offer tax incentives to affect the other aspects of agricultural irrigation, such as environmental impacts.[222] Implementing a tax system to encourage water efficient behavior balances marginal benefits and marginal costs.[223]

Providing subsidies for irrigation is a nearly universal practice.[224] "Input subsidies on agricultural water include subsidies on diesel fuel, electricity, or equipment;" subsidies can also include compensation to farmers who install efficiency-improving technology, such as a drip irrigation system.[225] The benefit from subsidies is difficult to track, and consequently, experts often question the effectiveness of subsidies.[226]

Water price refers to any charge or levy that irrigators pay to gain access to water for their fields.[227] Those individuals using the water should pay the cost of providing water, and this principle determines water pricing.[228] Water inputs or production outputs decide the pricing scheme.[229] Water inputs calculation is more common than production outputs, even though measuring output is generally easier.[230] Measuring input water use often requires additional equipment and can be cost prohibitive for some delivery systems.[231] Justified by the "user pays" principle, water pricing is the most common incentive that the World Bank promotes.[232]

218. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 53-54.
219. *See id.* at 22, 53-54.
220. *Id.* at 54.
221. Gonzalez & Salman, *supra* note 120, at 111.
222. *Id.*
223. *Id.*
224. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 54.
225. *Id.*
226. See *id.* at 53-54.
227. Gonzalez & Salman, *supra* note 120, at 106.
228. *Id.*
229. *Id.* at 107.
230. *Id.* at 107-08.
231. *See id.* at 11.
232. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra* note 46, at 54.

1. Water Rights

Ownership of a water right is similar to the ownership of any property. The government or water law systems govern the allocation of water rights, which are allocated based on either riparian, prior appropriation, or public allocation systems.[233] The benefit of owning water rights is that irrigators are allowed to rent, sell, or otherwise transfer these rights.[234] These benefits provide motivation for owners to maintain the integrity of water rights because they have the opportunity to sell or transfer them in the future.[235] Water right allocation is based on share of flow, quantity, or use, and is apportioned either by priority or by proportional division of expected shortages.[236] Selected approaches to water rights, such as those found in the some areas of the United States and Australia, only apply to surface water, and therefore, only apply to irrigators located along a watercourse.[237] Such a system is impractical for communities in South India that rely on tanks, or in South Asia where twenty million people pump groundwater for irrigation.[238]

E. GROUNDWATER RECHARGE

As discussed earlier, India receives nearly all its rainfall during the monsoon season, and much of the irrigation policy in place involves storing this water for use during the dry season.[239] However, another method of conserving water and increasing irrigation efficiency involves rejuvenating groundwater supplies *while* irrigating.[240] A shift in state policy from supplying water only in the dry season to supplying water during the monsoon season serves two purposes: (1) with the extra water supply farmers are able to grow water-intensive crops in the wet season; and (2) the water for irrigating fields will simultaneously recharge groundwater resources.[241]

This cycle of groundwater recharge and irrigation management could potentially increase the productivity of Indian farmers. Monsoons generally bring enough rain for farmers to have sufficient irrigation water; however, the monsoons are unpredictable, and there may be

---

233. Gonzalez & Salman, *supra* note 120, at 115-16; YACOV TSUR ET AL., PRICING IRRIGATION WATER: PRINCIPLES AND CASES FROM DEVELOPING COUNTRIES 29-30 (2004).

234. *See* Xinshen Diao, Terry Roe, & Rachid Doukkali, *Economy-Wide Benefits From Establishing Water User-Right Markets in a Spatially Heterogeneous Agricultural Economy* 17 (Int'l Food Policy Research Inst., TMD Discussion Paper No. 103, 2002), http://www.ifpri.org/sites/default/files/publications/tmdp103.pdf.

235. *Id.* at 16-17.

236. TSUR ET AL., *supra* note 233, at 30.

237. *The Challenges of Integrated River Basin Management in India*, *supra* note 12, at 2.

238. *Id.*

239. Iyer et al., *supra* note 70, at 188-90; *The Challenges of Integrated River Basin Management in India*, *supra* note 12, at 2.

240. Int'l Water Mgmt. Inst., *Innovations in Groundwater Recharge*, 1 WATER POLICY BRIEFING 1 (2002), http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/wpb01.pdf.

241. *Id.*

years when they do not bring enough.[242] Irrigation practices that help recharge groundwater supplies, which otherwise deplete sources at a much faster rate than typical recharge, allow for more certainty and less risk.[243] Moreover, farmers would be more likely to grow two successful crops per year, and those downstream, or who otherwise share the groundwater resource, can also benefit from the recharge.[244]

Implementing this groundwater recharge policy in Uttar Pradesh—located in the western Indo-Gangetic Plain—successfully raised the water table, which had been progressively declining.[245] Groundwater recharge provided farmers with needed irrigation water when they were unable to build dams, due to the flat terrain, overwhelming construction costs, and strict environmental standards.[246] While this recharge method may be region and climate specific, it provides the potential to improve the livelihood of farmers in regions with similar hydro-geological characteristics.[247]

F. FOOD TRADE

Food trade has the potential to significantly affect the amount and productivity of water use in irrigation. Growing food where water is abundant and trading it to a country that suffers from water shortage creates a virtual water trade.[248] "Virtual water" refers to the volume of water used to produce traded crops.[249] "People 'eat' between 2,000 and 5,000 liters of water per day—depending on [their] diet."[250] In the course of food trade, the importing country saves the water that farmers would have otherwise used to irrigate the crop.[251] While food trade occurs frequently worldwide and serves to reallocate irrigation water resources,[252] virtual water trade is unlikely to have a significant impact on irrigation productivity. Some regions suffer from such severe water scarcity or other unfavorable conditions for a certain crop, that their only option is importation.[253]

IV. PRO-POOR POLICIES IN DEVELOPING COUNTRIES

The majority of methods for improving irrigation productivity and efficiency require substantial investments in new infrastructure,

242. *Id.* at 6.
243. *See id.* at 2.
244. *See id.* at 5.
245. *Id.* at 2.
246. *Id.* at 3.
247. *Id.* at 1.
248. Int'l Water Mgmt. Inst., *Does Food Trade Save Water? The Potential Role of Food Trade in Water Scarcity Mitigation*, 25 WATER POLICY BRIEFING 1-2 (2007), http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/WPB25.pdf.
249. *Id.* at 2.
250. *Id.* at 3.
251. *Id.* at 2.
252. *See id.* at 3-4.
253. *Id.* at 6.

research, and the development and staffing of systems of irrigation management.[254] However, approximately 75% of the world's poor population currently lives in rural areas,[255] and many developing countries face challenges of limited technological and financial resources as well as uncertainty over agricultural water delivery arrangements.[256] There is a correlation between the proportion of people in a country who have access to irrigation water and the national per capita income;[257] and improving access to irrigation water is not an easy task.[258]

A. LOW-COST MICRO-IRRIGATION SYSTEMS

In past years, extensive research has gone into the development of new methods for delivering water to crops.[259] As discussed earlier, micro-irrigation, or the practice of frequent water application directly to the rootzone in smaller quantities, typically requires extensive infrastructure and maintenance.[260] Many of these technologies remain out of reach to farmers in low-income, rural regions.[261] However, micro-irrigation systems not only come in the highly commercialized, state-of-the-art varieties, but they also come in low-cost varieties.[262] The micro-irrigation industry began by developing complex irrigation systems for commercial farmers, but has since entered into a second phase with the goal of developing more feasible solutions for small-scale farming operations.[263] Low-cost micro-irrigation often takes the form of small-scale drip kits that are inexpensive and easy to install.[264] These drip kits allow the smaller farm operations to: (1) use water more efficiently and irrigate crops with precision; (2) improve the quality of their crop; (3)

---

254. *See* G. Cornish et al., *Water Charging in Irrigated Agriculture: An Analysis of International Experience*, 2004 FAO WATER REPORTS 28, ch. 5, *available at* http://www.fao.org/docrep/008/y5690e/y5690e00.HTM#Contents.

255. The World Bank, *Agriculture for Development*, 2007 WORLD DEVELOPMENT REPORT 45 (2007), http://siteresources.worldbank.org/INTWDR2008/Resources/WDR_00_book.pdf.

256. *See* Mark W. Rosegrant, Claudia Ringler, & Tingju Zhu, *Water for Agriculture: Maintaining Food Security Under Growing Scarcity*, 34 Ann. Rev. Env't & Resources 205 (2009), *available at* http://arjournals.annualreviews.org/doi/pdf/10.1146/annurev.environ.030308.090351.

257. P.B. ANAND, SCARCITY, ENTITLEMENTS AND THE ECONOMICS OF WATER IN DEVELOPING COUNTRIES 1 (2007).

258. *See id.*

259. Samyuktha Varma, Shilip Verma & Regassa E. Namara, *Promoting Micro-Irrigation Technologies That Reduce Poverty*, 23 WATER POLICY BRIEFING 1-2 (2006), *available at* http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/WPB23.pdf.

260. Dorota Z. Haman & Forrest T. Izuno, *Principles of Micro Irrigation*, AE70 U. FLA. INST. OF FOOD AND AGRIC. SCI. EXTENSION, May 1989 at 1, 3,5, *available at* http://edis.ifas.ufl.edu/WI007.

261. Samyuktha Varma et al., *supra* note 259, at 1.

262. *Id.* at 1-2.

263. *Id.* at 6.

264. *Id.*

reduce the amount of harmful insects, plant disease, and weeds; (4) reduce labor and energy costs; and (5) stretch their water resources into order to cultivate more land.[265] These improvements can have a significant impact on a farmer's earning margins.

One particular technology that has emerged as a low-cost micro-irrigation system is the Pepsee system.[266] Pepsee introduced its "Pepsee kit" in India in 1998; it is a low-grade, light-weight, "disposable" tubing used in drip irrigation systems, and the kits are spreading quickly.[267] Its attractiveness comes from its low cost, with installation costing less than Rs 1,000 per acre (or approximately USD$20 per acre).[268] This cost is less than half the cost of the alternative micro-tubes, and approximately 25% of the cost of conventional drip irrigation systems, while brand name drip irrigation systems can cost up to Rs 60,000, or USD$1200, per acre.[269] Pepsee caters its product to farmers who cannot afford a typical drip irrigation system.[270]

On farms in India where farmers have implemented Pepsee systems, farmers report an increase in productivity and an ability to cultivate and irrigate more farmland.[271] Although Pepsee is made of a low-grade material and is not a permanent system, it can provide a stepping stone for farmers to make that initial, inexpensive investment in a micro-irrigation system, increase their revenue, and build towards investing in a more permanent micro-irrigation system.[272]

The use of subsidies, as previously discussed, provides another solution for expanding the scope of micro-irrigation systems in poor countries, and for making them more available to poor farmers. In Gujarat, a state in western India, the state government has developed a subsidy scheme that takes into account the irrigators' socioeconomic status and the type of irrigation system installed to determine the subsidy rates.[273] Other subsidy programs create a "first mover" advantage to encourage farmers to take action to improve productivity sooner rather than later.[274] While in the some cases, poor farmers benefit from subsidies, others farm in countries where the government itself is too poor to provide subsidies.

---

265. *Id.* at 4.

266. FRANK RIJSBERMAN, THE WATER CHALLENGE 24 (2004), http://www.copenhagenconsensus.com/Files/Filer/CC/Papers/Sanitation_and_Water_140504.pdf.

267. *Id.*; *The Challenges of Integrated River Basin Management in India*, *supra* note 12, at 6.

268. RIJSBERMAN, *supra* note 266, at 25; *The Challenges if Integrated River Basin Management in India*, *supra* note 12, at 6.

269. RIJSBERMAN, *supra* note 266, at 25; *The Challenges of Integrated River Basin Management in India*, *supra* note 12, at 6.

270. *See* RIJSBERMAN, *supra* note 266, at 25.

271. *Id.*

272. *Id.* at 24-25.

273. Samyuktha Varma et al., *supra* note 259, at 6.

274. *Id.*

B. INFORMAL IRRIGATION

As mentioned earlier, some irrigators and irrigation systems suffer from low efficiency due to the lack of irrigation system management.[275] Across Africa, informal irrigation is widely used in urban agriculture, large farms, and backyard gardens.[276] Many low-income irrigators obtain their water directly from private community rainwater harvesting, as no governmental agencies or organized providers are involved.[277] However, informal irrigation practice creates a problematic situation in areas suffering from water shortage or inefficiency, as it results in a lack of control over the water resource.[278] Management is necessary for achieving basin-wide efficiency, yet these regions generally lack the resources and knowledge to develop an effective management system.[279] As discussed below, wastewater use is an example of a common form of informal irrigation.

C. WASTEWATER USE

Facing times of drought and other unpredictable environmental conditions, many farmers struggle with uncertainty in their water resource, and this uncertainty adds even more risk to the practice of farming. However, wastewater use for irrigation may alleviate some of this risk. Farmers in developing countries commonly utilize wastewater irrigation.[280] These practices sustain landless farmers who rent small parcels of farmland in Asia, Africa, and Latin America.[281] Moreover, wastewater irrigation benefits not only farmers, but also society as a whole. Nutrients carried in wastewater can replace the need for chemical fertilizers, saving farmers money and increasing crop yields.[282] In addition, wastewater production is continuous, meaning farmers enjoy more certainty in their water supply, even in the dry season.[283] With this certainty, farmers are more willing to invest in other inputs for their crops.[284] Additionally, many of these poor regions lack the funds available to build wastewater treatment facilities; and even in more developed nations, the required capital investment makes the

275. SHAPING THE FUTURE OF WATER FOR AGRICULTURE, *supra*, note 46, at 4.

276. Pay Dreschsel & Samyuktha Varma, *Recognizing Informal Irrigation in Urban and Peri-Urban West Africa*, 26 WATER POLICY BRIEFING 1, 2 (2007), http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/WPB26.pdf.

277. *The Challenges of Integrated River Basin Management in India*, *supra* note 12, at 3.

278. *See* Dreschsel & Varma, *supra* note 276, at 2.

279. *Id.*

280. Int'l. Water Mgmt. Inst., *Confronting the Realities of Wastewater Use in Agriculture*, 9 WATER POLICY BRIEFING 1 (2003), http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/wpb09.pdf [hereinafter *Confronting the Realities of Wastewater Use in Agriculture*].

281. Int'l Water Mgmt. Inst., *Reuse of Wastewater for Agriculture*, http://www.iwmi.cgiar.org/health/wastew/ (last visited Oct. 18, 2009) [hereinafter *Reuse of Wastewater for Agriculture*].

282. *Confronting the Realities of Wastewater Use in Agriculture*, *supra* note 280, at 1.

283. *Id.*

284. *Id.*

construction of such treatment plants unfeasible.[285] In these communities without a wastewater treatment plant, wastewater that is not used for irrigation is discharged into surface water resources, negatively affecting the health of downstream users.[286] In contrast, wastewater irrigation creates a more sanitary means of discharge.[287] Scientists have discovered that certain contaminants leach out of the water when it is applied to fields, which improves the quality of water that seeps down into groundwater supplies.[288]

However, wastewater irrigation poses some health risks. In Pakistan, studies showed that the number of cases of diarrhea and infection with hookworms and roundworms were higher among wastewater farmers.[289] However, solutions to these problems are easy and inexpensive: farmers can control hookworm and roundworm infections by simply wearing gloves and shoes while working the fields.[290]

In general, developing countries use wastewater to irrigate agriculture.[291] Developed countries with more stringent environmental regulations may limit use of wastewater for irrigation; however, there are a few exceptions, and water reclamation is an increasing practice in the United States.[292] Farmers in North and South Carolina have been recycling livestock wastewater for irrigation of their hay crops.[293] Scientists conducted studies on these crops, comparing yields from crops irrigated with pretreated livestock wastewater and those irrigated with well water and treated with fertilizer.[294] Crop yields were higher where irrigated with the pretreated swine wastewater irrigation.[295]

Effective reform, management, and education regarding the risks are the keys to successfully and safely practicing wastewater irrigation. Once these are accomplished, the practice of waste water irrigation can be a very effective tool.[296]

---

285. *Id.* at 3. ("[A] [treatment] plant proposed for use in Guanajuato City, [Mexico]...was estimated to cost US$2.6 million to build, and a further US$200,000 per year to run.").

286. *Id.*

287. *Id.* at 1.

288. *Id.* at 3.

289. *Id.* at 4.

290. *Id.* at 5.

291. *Reuse of Wastewater for Agriculture, supra* note 281.

292. Peter S. Cartwright, *The Case for Industrial Water Reuse - A Looming Necessity*, INDUSTRIAL WATERWORLD, Sept. 1, 2009, *available at* http://www.waterworld.com/index/display/article-display/5727769438/articles/waterworld/industrial-water/water-reuse/2009/09/the-case_for_industrial.html (last visited Oct. 19, 2009).

293. *Wastewater Irrigation Effective On Bermudagrass Hay*, SCIENCE DAILY, Feb. 9, 2009, *available at* http://www.sciencedaily.com/releases/2009/01/090131122554.htm (last visited Oct. 19, 2009).

294. *Id.* (pretreating livestock wastewater included removal of concentrations of ammonia, nitrogen, and phosphorous).

295. *Id.*

296. *Confronting the Realities of Wastewater Use in Agriculture, supra* note 280, at 1,5.

CONCLUSION

While this article presents an international study of irrigation policy and reform, the implementation of irrigation policy is not an international notion. Although water issues are often transboundary and of international concern, there is no one-size-fits-all rule for developing an effective policy with international applications. The first obstacle is that one body of water law simply cannot be enforced worldwide, as there is no global governing body. The second obstacle is that diversity in crops, landscape, climate, weather, politics, and historical uses requires more than one solution. For example, in New South Wales, Queensland, and Victoria, Australia, water law allows every occupier of no more than two hectares free access to water for domestic and livestock use, including non-commercial crops.[297] If India were to adopt this law, over 80% of all land and 90% of water users would have free access to water resources, which would vastly over-allocate available water.[298] Because of the Tennessee Valley River Authority Model's success, the Damodar Valley Authority in India attempted to implement the same model, but was unsuccessful.[299]

The heterogeneity of agricultural land, climate, historic practices, and water resources makes it impossible to devise one worldwide irrigation policy.[300] However, irrigation policy and reform should be a worldwide endeavor, with each country and region implementing its own policies. With 70% of the freshwater supply going to agricultural production, there is plenty of need for improvement, which would have a significant and positive impact on the worldwide issue of water scarcity.

Participatory irrigation management in its various forms is almost always successful.[301] This practice has been implemented in various ways, from creating an open water market, as Australia has done, to inviting local farmers to participate in governmental decision-making as many regions of South Africa practice.[302] The challenge agricultural regions face is striking an effective balance between state control and farmer participation. India and China have both encountered challenges and experienced failures in employing participatory management schemes, but both countries continue to work towards developing a system that works.[303] Africa faces the issue that the wealthy farmers

---

297. *The Challenges of Integrated River Basin Management in India*, *supra* note 12, at 4.

298. *Id.*

299. *Id.* at 1.

300. Xinshen Diao et al., *supra* note 234, at 1.

301. THE WORLD BANK, CASE STUDIES IN PARTICIPATORY IRRIGATION MANAGEMENT 1-2 (David Groenfeldt & Mark Svendsen eds., 2000), *available at* http://go.worldbank.org/WD2F2ZB0U1.

302. *Compare The Challenges of Integrated River Basin Management in India*, *supra* note 12, at 4 (explaining that Australian law allows occupiers of land free access to water up to a certain amount), *with* Easter & Zekri, *supra* note 203, at 6 (stating that water irrigation boards are made up primarily of private, farmer-managed, water systems).

303. Iyer et al., *supra* note 70, at 185-86, 198-99.

maintain the majority of control, while smallholders and other poor farmers have little to no impact on irrigation management.[304] These countries provide examples from which to learn, and policy reform can address these issues. When the goal is_to increase productivity, individuals, who are out in the fields and have intimate knowledge of farming the land, must be involved in the decision-making process.

Some say that irrigation reduces poverty. Irrigation alone will not reduce poverty; however, irrigation with increased productivity, more efficient resource use, and increased profit margins will help to alleviate poverty.[305] The farmer's share of food production can be anywhere from 3% to 34% for most individual food products.[306] Farmers often operate on very narrow profit margins and assume substantial risks, including adverse climate conditions, the possibility of pests or crop disease, and the uncertainty of water supply.

Countries face a common problem implementing policies that require farmers to invest in new, more efficient irrigation technologies that is simply impractical in poor regions where farmers do not have the necessary capital. Also, public subsidies and tax incentives have limited effects. Instead of looking to governmental subsidies, farmers could turn to private capital investors. Farmers in developing countries typically maintain a higher percentage crop share because they purchased food closer to its raw form.[307] Therefore, for highly marketable crops, investors could contract for a portion of the crop share to trade in the global market as repayment for their investment. While this may not be a feasible solution for the poorest farmers with no access to global trade resources and information, it may be effective in countries such as China and India, who regularly trade in the global food market.

While many poorer regions of Africa and India currently utilize wastewater irrigation, this policy could be implemented on a broader scale internationally. Using wastewater for irrigation solves several problems farmers face by providing both nutrients that can be costly to purchase and a method of disposal for polluted water. With adequate controls and further research, wastewater irrigation could have multiple uses, including application in environmental policies.

Irrigation water policy on an international level is a very complex

---

304. *See* James Cullis & Barbara van Koppen, *Applying the Gini Coefficient to Measure Inequality of Water Use in the Olifants River Water Management Area, South Africa* 9 (Int'l. Water Mgmt. Inst., Research Report 113, 2007), http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB113/RR113.pdf.

305. *See generally* The Role of Agriculture in the Development of LDCs and their Integration into the World Economy, Paper Prepared for the Third United Nations Conference on the Least Developed Countries §§139-43 (May 14-20, 2001), *available at* http://www.fao.org/docrep/003/Y0491E/y0491e00.HTM (describing the affects of agricultural productivity on poverty); Iyer et al., *supra* note 70, at 122-23 (explaining the problems associated with inefficient water use); Weersink et al., *supra* note 158, at 47 (explaining the affects of changing margins in agriculture).

306. *See* Weersink et al., *supra* note 158, at 38.

307. *Id.*

issue, and "understanding water resources requires the skills of agronomists, economists, engineers, environmentalists, geographers, hydrologists, lawyers, planners, political scientists, and many others."[308] While countries continue to apply various types of reform, promote conservation practices, provide new technology, improve management, and coordinate water users, water productivity will be an ever-changing practice, but there are several areas where more research is necessary. This list includes crop breeding and biotechnology, management of competing uses such as municipal use, co-management of irrigation policy and environmental policy, and the interaction between management at different levels. International experiences, especially the thriving water markets in Chili, productive drainage projects in Egypt, successful privatization of water rights in Australia, new irrigation technology and biotechnology in the United States, and farmer cooperation in Guatemala provide many innovative learning opportunities.

308. MERRETT, *supra* note 3, at 200-201.