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FAO REGIONAL CONFERENCE FOR ASIA AND THE PACIFIC

Thirty-fifth Session

1-4 September 2020[1]

Setting regional priorities to manage water for agriculture under conditions of water scarcity

Executive summary

Water scarcity is emerging as a more immediate challenge than climate change in Asia and the Pacific region, driven by a range of demographic and economic pressures that increase water demand as well as by climate change itself. Agriculture, the major consumer of freshwater in the region, is a driver of water scarcity and also is impacted by competitive water development within the sector and, increasingly, from higher-value uses in industry and water supply and sanitation.

This document briefly introduces the challenge and highlights the lack of reliable information and data on water resources availability, quality and use. This underwrites the need for good water accounting and the development of clear and rational water allocation processes.

The productivity of agricultural water use, particularly in irrigation, will need to increase to match food demand and meet food security policy targets; indeed, agriculture will need to use the same amount of water, or in many cases even less, than in the past. Although the need to preserve and enhance natural ecosystems is well appreciated, water policy and water allocations do not yet address needs for environmental water, and as they begin to do so, there will be further pressure on agricultural water supplies.

FAO's Regional Office for Asia and the Pacific is developing a regional programme of action on water scarcity that is currently in a scoping phase to mid-2020. Ultimately it will focus on responses and adaptations to water scarcity in the agricultural sector. The final section of this paper outlines the key components of this programme and the expected outputs from the scoping phase. It seeks advice from the Regional Conference on how best to support countries to tackle water scarcity in agriculture and how to bring the collective power of regional action and mutual support to effectively address these challenges.

Suggested action by the Regional Conference

The Regional Conference is invited to:

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[1] Rescheduled from 17-20 February 2020, Thimphu, Bhutan

- note that addressing water scarcity in agriculture is essential to making progress towards the Sustainable Development Goals, especially those related to water security, food security and poverty eradication;
- share national actions, experiences and knowledge on water scarcity management in agriculture, including best practices in water assessment, digital innovation and water governance (e.g. legal, institutional and financing frameworks) related to maximizing the social, economic and environmental benefits from water uses;
- endorse FAO's efforts to support countries in managing water scarcity via its Water Scarcity Programme; and
- advise FAO on key priority actions for its Water Scarcity Programme, including actions to be taken by FAO towards activating regional (or subregional) mechanisms to increase coordination among national efforts to address water scarcity.

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Introduction

1. Addressing water scarcity[2] in agriculture while simultaneously making more water available for other uses and protecting the ecological support functions of freshwater systems will be one of the most difficult and important challenges of this century. Water scarcity arises when demand exceeds available supply, whether supply is limited by uncoordinated planning and inadequate hydraulic infrastructure or by the physical availability of water itself.[3]

2. Two-thirds of the world's population currently live in areas that experience water scarcity for at least one month a year.[4] An increasing number of experts now claim that we are rapidly approaching the maximum global potential for consumptive freshwater use (and in many areas consumption already exceeds supply as evidenced by falling groundwater levels and drying rivers).[5]

3. The drivers of water scarcity are well known: population growth, rising wealth, changing diets towards increased meat and dairy consumption, and expanding biofuel production. All of these will continue to drive the demand for water (and energy and land). The pattern of rapid urban development in Asia (predominantly coastal) is of most concern to planners and water managers.

4. Asia and the Pacific region contains a highly diverse range of countries and climates that experience water scarcity of varying types and severities – from absolute water scarcity[6] in arid and semi-arid regions (i.e. large parts of South Asia and East Asia) to seasonal or interannual scarcity where high variability means that scarcity is experienced for parts of the year (i.e. monsoonal Southeast Asia). The region also encompasses approximately 30 000 islands scattered over 30 million km^2, most of which are located in the tropical and subtropical zones of the central and southern Pacific Ocean.[7] The Pacific Islands face unique water scarcity challenges as they are often reliant on limited groundwater supplies that are vulnerable to pollution and saline intrusion.[8]

5. The Sustainable Development Goals set multiple challenges for agriculture to contribute to poverty reduction, adequate nutrition and food security, while minimizing contributions to greenhouse gases and transforming production systems into ones that are environmentally sustainable. FAO's Global Framework for Action[9] sets a path to achieve food security and poverty reduction, while coping with water scarcity and mitigating and adapting to climate change.

Water scarcity and agriculture

6. Agriculture is both a driver and a victim of water scarcity. Agriculture drives water scarcity because evapotranspiration from irrigated agricultural land is by far the largest consumptive use of water withdrawn for human use. In some countries, 90 percent or more of diverted water resources are

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[2] Defined simply as the excess of demand relative to supply. For a comprehensive discussion of the definition see 'Coping with Water Scarcity' (FAO, 2012).

[3] FAO. 2012. Coping with water scarcity: an action framework for agriculture and food security. FAO Water Reports, 38.

[4] UNESCO. 2012. World Water Development Report Volume 4: Managing Water under Uncertainty and Risk. UN Water Report (Vol. 1). https://doi.org/10.1608/FRJ-3.1.2

[5] Kummu, M., Guillaume, J. H. A., De Moel, H., Eisner, S., Flörke, M., Porkka, M., Ward, P. J., *et al.* 2016. The world's road to water scarcity: Shortage and stress in the 20th century and pathways towards sustainability. Scientific Reports, 6 (November), 1–16. https://doi.org/10.1038/srep38495

[6] Absolute water scarcity is defined as an insufficiency of supply to satisfy total demand after all feasible options to enhance supply and manage demand have been implemented. FAO. 2008. Coping with water scarcity – an action framework for agriculture and food security. FAO Water Report 38. Rome.

[7] White, I. & Falkland, T. 2010. Management of freshwater lenses on small Pacific islands. Hydrogeology Journal 18: 227–246.

[8] Note that an excess of water, in the form of floods, is also a significant challenge in Asia, but that is beyond the scope of this paper.

[9] FAO. 2016. Global Framework for Action.

used in irrigation, with the remainder used for drinking water supply, sanitation, industry, mining, navigation, amenity and environment.[10] In countries that are highly dependent on irrigation, such as Pakistan, irrigated agriculture consumes more than 70 percent of annual average water resource availability.[11] Privately developed groundwater now supports a larger area of irrigation in India than the area supported by all the surface irrigation investment by the states. It is unregulated, unsustainable in many places, and a key player in the electricity crises facing at least three major states.[12] In China, where industrialization and urbanization have accelerated over the past 20-30 years, the proportion of total water use by agriculture has fallen from around 90 percent of diverted water resources to around 60 percent and is expected to decline to 50 percent by 2030.

7. Agriculture is also a victim of water scarcity – in particular, the scarcity that is driven by rapidly escalating industrial and urban water pollution which makes water unsuitable or unsafe for food production. While the common practice of reusing urban or industrial wastewater can help to mitigate water scarcity, wastewater irrigation, if not properly managed, can harm crop quality, impair human health and cause environmental damage. Urban wastewater often has high concentrations of heavy metals, particularly in cities with heavy industry. When crops are regularly irrigated with recycled water, concentrations of heavy metals build up in the soil. This can be harmful to crop production—reducing the yield benefits of wastewater irrigation over time—and to humans and animals who consume the metal-rich plants.[13]

8. Since the advent of the Green Revolution, irrigation has been the main intervention to assure the reliability and productivity of cropping in Asia and has played a significant role in economic development, alleviating rural poverty, reducing food prices and enhancing household and national food security. This is especially true in Asia where area equipped for irrigation has grown enormously over the past five decades, particularly in China (from 45 to 68 million hectares) and India (from 26 to 67 million hectares).[14]

9. Asia's countries with the highest levels of water withdrawals for irrigated food production are those that are increasingly water scarce, which is evidence that hydraulic infrastructure (particularly small-scale groundwater pumping) has been overdeveloped in relation to available water supplies.[15] A recent report from the The Organisation for Economic Co-operation and Development (OECD) places Asia's irrigation-dependent food baskets in Northwest India and North China as two of the world's top three hotspots in terms of water-related risks to food production.[16]

10. A further characteristic of Asian agriculture that is closely related to unsustainable water use is the relatively recent (and ongoing) expansion in groundwater irrigation – especially in South Asia and East Asia but also in parts of Southeast Asia (such as the Central Highlands of Viet Nam and the Central Dry Zone in Myanmar). While the growing use of groundwater has improved the livelihoods of millions of rural people,[17] it has also caused depletion of aquifers, pollution of groundwater and the

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[10] WWAP (World Water Assessment Programme). 2012. The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk. Paris, UNESCO. (Available at: http://unesdoc.unesco.org/images/0021/002156/215644e. pdf).

[11] Young, W. J., Anwar, A., Bhatti, T., Borgomeo, E., Davies, S., R. Garthwaite III, W., E. Gilmont, M., Leb, C., Lytton, L., Makin, I., & Saeed, B. 2019. "Pakistan: Getting More from Water." Water Security Diagnostic. World Bank, Washington, DC.

[12] Shah, T. 2009. Taming the anarchy: groundwater governance in South Asia. Washington, DC, USA: Resources for the Future; Colombo, Sri Lanka: International Water Management Institute (IWMI). 310 pp.

[13] Damania, R., Desbureaux, S., Rodella, A.S., Russ, J., & Zaveri. E. 2019. Quality Unknown: The Invisible Water Crisis. Washington, DC: World Bank. doi:10.1596/978-1-4648-1459-4. L

[14] Scheierling, S. M., & Treguer, D. O. 2016. Enhancing Water Productivity in Irrigated Agriculture in the Face of Water Scarcity, 31, 1–10.

[15] Molle, F. 2008. Why enough is never enough: The societal determinants of river basin closure. International Journal of Water Resource Development, 24(2), 247–256.

[16] OECD. 2017. Water Risk Hotspots for Agriculture. https://doi.org/10.1787/9789264279551-en

[17] Kulkarni, H., Shah, M., & Vijay Shankar, P. S. 2015. Shaping the contours of groundwater governance in India. Journal of Hydrology: Regional Studies, 4, 172–192. https://doi.org/10.1016/j.ejrh.2014.11.004

intrusion of seawater in coastal aquifers upon which coastal cities (and future generations) depend. With the advent of cheap pumps and widespread electrification, groundwater use has exploded across Asia over the past 25 years, resulting in many cases in both unsustainable overdraft and increasingly expensive and high carbon-emitting energy use.

11. The situation is perhaps most urgent in India where six of the most important agricultural states are overexploiting groundwater to meet current irrigation demands. According to data from the United States of America's National Aeronautics and Space Administration's Gravity Recovery and Climate Experiment, northwest India had the highest groundwater depletion rates in the world in 2002–2008, even though precipitation was above normal for the period.[18] Northwest India's collective water deficit totals an estimated 100 x 10^9 m^3 per year, a volume of water that exceeds the average annual flow of the Nile River.[19] As a result, freshwater aquifer levels are falling by between one to three metres per year in some areas.

12. Given the widespread, high-impact and intensifying use of water for agriculture, adjusting the way in which agriculture water withdrawals and discharges are managed and governed offers an opportunity to both predict and mitigate the impacts of water scarcity.[20]

Groundwater dilemmas

The groundwater revolution across Asia has dramatically increased crop production and improved livelihoods, but at the expense of unsustainable use and local crises in electricity provision. There are perhaps 20 million groundwater irrigators and in excess of 14 million tube wells in India, posing massive governance challenges because of the transaction costs of conventional demand management measures, such as licensing and metering[21]. The result has been competitive abstraction, falling water tables and a "race to the bottom", which has even resulted in exhausted aquifers, for example in northern Gujarat.

Historically in richer countries, licensing of groundwater has lagged that in surface water systems, because of notions of ownership of the overlying land (riparian doctrine), open access through pumping, and the challenges of identifying and metering pumpers.

In China, technological innovation, in the form of "smart card" operation of groundwater pumps, has allowed individual accounting of groundwater use and application of quotas by group and by user in sensitive areas with rising overdrafts, notably in the North China Plain. Both flows and electricity use are monitored, and if individual users exceed their quotas, they must pay penalty water charges. The corollary incentive is that charges are waived if users are under quota.

Groundwater has great strategic value in coping with drought and in ensuring stable water supply across years with variable rainfall and surface water supply. Sustainable long-term management of groundwater could, in theory and in some aquifers, allow short-term overdrafts in low water availability years, balanced by recharge in wetter than average years. The introduction of water management based on evapotranspiration quotas and monitoring is intended to achieve a balanced and strategic use of groundwater in the North China Plain.

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[18] Birkenholtz, T. 2017. Assessing India's drip-irrigation boom: efficiency, climate change and groundwater policy. Water International Journal, 42(6).

[19] Postel, S. L. 2000. Entering an Era of Water Scarcity: The Challenges Ahead. Ecological Applications, 10(4), 941–948.

[20] Moriarty, P., Butterworth, J., & Batchelor, C. 2004. Integrated Water Resources Management. Water Science and Technology, 62(4), 353–63. https://doi.org/10.2166/wst.2010.262

[21] Shah, T., Scott, C., Kishore, A. & Sharma, A. 2007. Energy Irrigation Nexus in South Asia, Improving Groundwater Conservation and Power Sector Viability: Ch 11. In eds Giordano M and Villholth K, The Agricultural Groundwater Revolution. Opportunities and threats to Development. CABI

Water scarcity and climate change

13. As climate changes and the world warms, the water cycle speeds up and global rainfall volume increases while local rainfall becomes more variable in intensity, duration and location.[22] It is therefore expected that current challenges will be exacerbated by climate change in the form of more frequent and intense droughts, floods and cyclones, melting glaciers, shifting monsoons, higher temperatures and disruption to groundwater recharge.[23] [24] Drought can be considered a primary form of water scarcity, and the frequency of droughts, already severe in countries such as Pakistan and India, is rising across the region, including in Indonesia, Viet Nam and large parts of Southeast Asia.[25] The small island developing states are highly vulnerable to climate change, particularly with accelerating saltwater intrusion into aquifers and more intense and frequent extreme events.[26]

Impacts of water scarcity on food security and livelihoods

14. A failure to confront the impacts of freshwater scarcity results in suboptimal use of water and negatively impacts food production in Asia in a variety of ways. Farmers (usually poor, marginalized and/or at the tail end of irrigation schemes) may lack sufficient water to irrigate crops when needed, leading to reduced yields and incomes or complete loss of crops and the capital invested in them.[27] Water scarcity may prevent farmers from flushing salts from the soil, reducing future productivity or requiring the land to be abandoned.[28]

15. Critically, water scarcity and unsustainable water use impact not only agricultural production, but the ecosystem services upon which our food production systems and overall food security depend.[29] Regulation and reduction of natural flows by dams, water withdrawals, diversion and land use changes for irrigation have already impaired the ability of many ecosystems to provide valuable ecosystem goods and services, including flood protection, water purification, biodiversity and critical habitats including wetlands and estuaries.[30] A number of iconic Asian rivers, including the Indus in South Asia and the Yellow in China, no longer reach the sea for parts of the year.[31] Many rivers have become so depleted that they lose their ability to support productive fisheries[32] or dilute pollutants.

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[22] IPCC. 2013. In: Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Eds.), Climate Change 2013: the Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA 1 535 pp.

[23] Taylor, R. G., Scanlon, B., Döll, P., Rodell, M., Van Beek, R., Wada, Y., Treidel, H., *et al.* 2013. Groundwater and climate change. Nature Climate Change, 3(4), 322–329.

[24] UNESCO. 2012. World Water Development Report Volume 4: Managing Water under Uncertainty and Risk. UN Water Report (Vol. 1). https://doi.org/10.1608/FRJ-3.1.2

[25] ESCAP. 2019. Ready for the dry years: Building resilience to drought in Southeast Asia. Bangkok. ISBN: 978-92-1-120787-3

[26] Freitas, C.R., Helbigb, H., Matzarakisc, A. 2014. Hydroclimatic assessment of water resources of low Pacific islands: evaluating sensitivity to climatic change and variability International Journal of Climatology. 34:881-892.

[27] Hussain, I., Yokoyama, K., & Hunzai, I. 2001. Irrigation against Rural Poverty: An Overview of Issues and Pro-Poor Intervention Strategies in Irrigated Agriculture in Asia. National Workshops on Pro-Poor Intervention Strategies in Irrigated Agriculture in Asia.

[28] Seckler, D., Molden, D., & R., B. 2006. Water Scarcity in the Twenty-First Century. International Journal of Water Resources Development.

[29] Postel, S., & Carpenter, S. R. 1997. Freshwater ecosystem services. In G. Daily (Ed.), Nature's services (pp. 195–214). Washington, D.C., USA: Island Press.

[30] Rijsberman, F. R. 2004. Water scarcity: Fact or fiction? Proceedings of the 4th International Crop Science Congress, 1 26 Sep – 1 Oct 2004, 80, 5–22. https://doi.org/10.1016/j.agwat.2005.07.001

[31] Postel, S. L. 2000. Entering an Era of Water Scarcity: The Challenges Ahead. Ecological Applications, 10(4), 941–948.

[32] Welcomme, R. L., Baird, I. G., Dudgeon, D., Halls, A., Lamberts, D., & Mustafa, M. G. 2016. Fisheries of the rivers of Southeast Asia. In J. F. Craig (Ed.), Freshwater Fisheries Ecology (pp. 363–376). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118394380.ch29

Water accounting and water allocation

16. In order to understand water scarcity, we need to know and quantify how much water is available for human use and how much is being used. Equally importantly, we need to know where and when that water is available, and this requires an understanding of the pathways through which water flows and is stored (particularly because water is a “fugitive” resource that seeps and flows across the landscape, vaporizes into the air and falls as rain and snow). In natural conditions, water is stored in lakes, which nevertheless drain continuously, and in underground water, where it may rest for years, even centuries.

Quantifying water use with water accounting

17. The nature of water poses considerable challenges to quantification. It is possible to measure: (1) flows at selected points in rivers and streams; (2) groundwater levels; (3) flows diverted into canals and in and out of reservoirs, and (4) the volume held in storage. Yet even with modern technologies, we have to estimate quantities – a small number of rain gauges that are many kilometres apart will not be able to quantify the exact volume of water that has fallen on the catchment.[33] Technologies such as remote sensing and hydrological modelling allow us to improve our estimates (e.g. the levels of evaporation from vegetation, land and water) and to represent patterns of water availability. But it remains difficult to quantify water in very low flow conditions and during floods.[34] Long-term records help us understand variability and trends so that we know, for example, if rain and snowfall are changing or if river flows to the sea are declining or failing on a seasonal or annual basis.

18. Quantifying water availability and use is known as water accounting**.**[35] It is desirable to be able to account for water long before water scarcity is apparent, and it is essential once there is competition between different uses and users, including those in the same place and those far apart but connected to the same river or aquifer. Water accounting is fundamental to allocate scarce water resources effectively and efficiently to different uses and users.

Water accounting fundamentals

19. A baseline assessment or review of water availability and current and projected use is the first step in the development of a functional water accounting system. Such reviews also have been conducted where water allocation and accounting systems are well established[36] but are dysfunctional or stressed in some new way, for example, by large increases in urban or industrial demand, or because of a revision of priorities such as the realization that far larger volumes of water must be retained to maintain healthy rivers, aquatic ecosystems and coastal zones.

20. Baseline assessments are highly desirable throughout Asia to: (1) set a reference against future changes and development; and (2) to better understand variability in resource availability and its implications. A major challenge for water accounting in general, and baseline assessments in particular, is a lack of long, consistent and representative records of rainfall, flows and associated meteorological data that can be used to estimate water use by vegetation. Data obtained from satellites can provide increasingly accurate and reliable estimates of the two largest components of water balance: (1) precipitation and (2) evaporation/transpiration (water evaporated through plants as a by-product of photosynthesis), and this provides a starting point for water resources assessment when conventional data are limited.[37] Without knowing the details of stocks and flows of streamflow and groundwater, it is possible to develop seasonal and annual water balances for catchments, river basins

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[33] Beven, K. 2012. Rainfall-runoff modelling: The primer. UK, Wiley-Blackwell.

[34] Beven, K. 2015. Facets of uncertainty: epistemic uncertainty, non-stationarity, likelihood, and communication. Hydrological Sciences Journal.

[35] FAO. 2017. Water Accounting and auditing – a source book. FAO Water Report 43. Rome.

[36] Murray Darling Basin Ministerial Council, 1996. Setting the Cap. Report of the Independent Audit Group ISBN 1 875209 96 4

[37] Karimi, P., Bastiaanssen, W.G.M. & Molden, D. 2013a. Water accounting (WA+) – a water accounting procedure for complex river basins based on satellite measurements.

and countries,[38] and while this can give a coarse understanding, we need to know the stocks and flows within the basin over space and time in order to manage water effectively.

21. In a baseline assessment, there needs to be an inventory of uses and users (principally irrigated, agricultural, domestic, industrial and environmental) that includes their location and an estimate of their water use. Where there are measurements (metering) or records, they can be analysed and assembled to create a water balance. Where there are no effective records, it is likely that new metering and measurement will be required for the assessment period. Estimates of use can also be made using remote sensing-derived water balance information and available proxy information, such as: (1) the electricity used for water pumping; and (2) survey data on hours of supply and capacities in urban water supply networks. Projected demands can be estimated from trends in urbanization, industrial development and the population's food needs, with associated norms (e.g. daily per capita water need) or expected changes.

22. Research over the past 25 years has demonstrated the need for a further refinement in understanding water use, i.e. the distinction between (1) consumptive use and non-consumptive use; and (2) recoverable and non-recoverable return flows[39] and whether they are beneficial or not (Figure 1). The main example of consumptive use is the amount of water depleted from a water system by crops and vegetation as evaporation and transpiration. Once vaporized, this water eventually returns as precipitation, but is lost to the river basin from which it came, thus reducing the volume of water available for other uses further downstream. An example of non-consumptive use is in hydropower generation: water flows through the turbines but continues to flow downstream and can be used again. Similarly, domestic water use does not deplete the volume flowing through the system, although it does diminish the quality of the return flows. If these are treated, then up to 95 percent of the water diverted for drinking water and sanitation is returned to the river basin and is available for reuse.

23. To understand a water balance and the water available to different users at different times, the notion of consumptive use (depletion) is very important, both in river and groundwater systems and in landscapes. When water is diverted for irrigation and consumed by crops, the resource available further downstream is reduced. Equally, recent experience with extensive watershed development in India has shown that intensive water harvesting and retention in upper catchments similarly reduces water availability in streams and groundwater in the lower reaches of the river and plains.[40] If the depletion of water at a basin scale is high, then the opportunities to increase water use at lower scales (i.e. catchment, irrigation system) are limited.

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[38] Molden, D. 1997. Accounting for water use and productivity. SWIM Paper 1. Colombo, Sri Lanka: International Irrigation Management Institute.

[39] Molden, D., Murray-Rust, H., Sakthivadivel, R. & Makin, I. 2003. A water- productivity framework for understanding and action. In: Kijne, J.W., Barker, R., Molden, D. (Eds). *Water productivity in agriculture: Limits and opportunities for improvement.* Wallingford, IWMI & CABI Publishing, pp. 1–18.

[40] Calder, I., Gosain, A., Rama Mohan Rao, MS., Batchelor, C., Garratt, J., & Bishop, E. 2007. Watershed development in India. New approaches for managing externalities and meeting sustainability requirements. Environ Dev Sust DOI 10.1007/s10668-006-9073-0

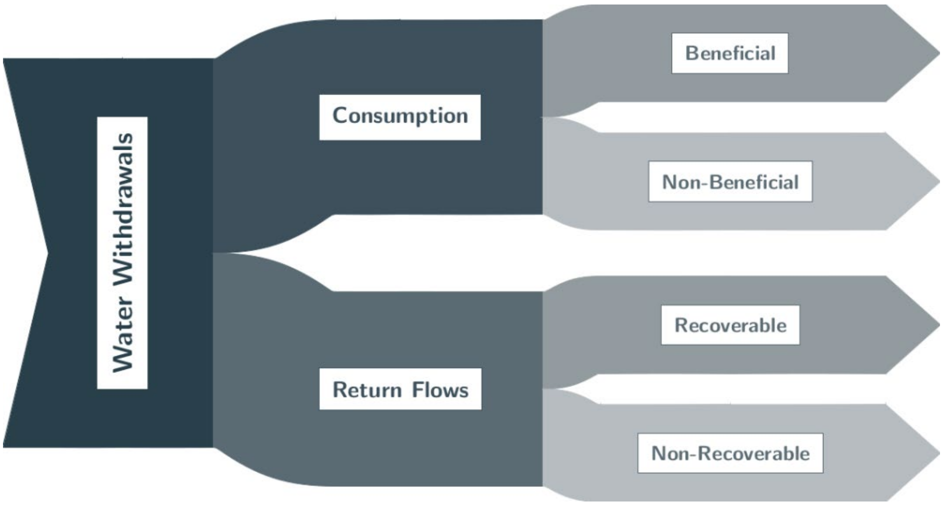

Figure 1. Water balance and the possible outcomes of water abstraction[41]

24. Since irrigated agriculture is the largest user of water by volume and the lowest value use of water, it is inevitable that when supplies are limited or unreliable, priority in allocation goes to drinking water supply, sanitation and industry. Whether legally sanctioned or not, water is transferred to higher-value uses and is acquired by those with money, power and influence when they need it. Formal water allocation processes are often designed with the intention of balancing demand with supply, overseeing orderly transfers between sectors and ensuring compensation for those who lose access to water. There are many practical advantages to developing a clear water allocation process before scarcity emerges, especially in managing highly variable annual water supplies (as in Australia's Murray Darling Basin).[42]

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[41] Pérez-Blanco CD, Hrast-Essenfelder A and Perry C, 2019. Irrigation technology and water conservation: from *panaceas* to actual solutions. Draft paper under review. Pers. Comm. Perry C. 2019.

[42] Turral, H. & Wood, M. 2013. Review of Irrigation Modernisation in Australia, World Bank, Washington.

Water accounting in China

In China, water is allocated to different sectors (e.g. agriculture, urban and rural domestic, sanitation, industry, environment) within a limit on total water use (a “cap”) at the national level and in each major river basin. Quotas are issued to each province within a basin and then to each county administration, with defined priorities for high-value uses (e.g. industry, urban and rural water supply and sanitation). The residual volume is allocated annually on the basis of quotas for irrigated agriculture, aquaculture and other primary production.

Water accounts are created to assess the volume of water resources available at basin and subsidiary levels, to incorporate long-term interannual variability in rainfall and weather, and to estimate water availability. Available water includes water stored in dams/reservoirs and underground. Accounts are also calculated for existing use in all sectors and for predicted demands in the near and medium term. Where there is interaction between surface and groundwater, more sophisticated assessments of both availability and use are required to avoid “double” counting.

The accounts are updated through the year and reassessed at the beginning of each “water year”. Water accounts are typically constructed on the basis of catchment-scale hydrologic modelling, requiring data on rainfall, evaporation and transpiration and streamflow over the entire landscape. In China, remote sensing is being used to quantify the evapotranspiration from all vegetative covers in a basin, allowing better calibration of hydrologic models and also monitoring of actual water use in irrigated areas.

Water accounting includes sophisticated approaches to demand forecasting on the basis of demographic change, urbanization, industrialization and energy production. In nearly all countries in the Asia Pacific region, the total volume of water available for human use is limited by its quality because of salinization, pollution from settlements and industry, and diffuse non-point sources of pollution from agriculture. In groundwater, suitability for certain uses can be limited by the presence of arsenic, fluoride (at certain concentrations) and nitrates, which pose threats to human health. Therefore, water accounting may include assessment, measurement and monitoring of water quality as well as quantity.

Sustainable use of water at basin scale can be defined in terms of a sustainable diversion limit[43], which is set in regard to maintaining healthy and effective aquatic ecosystems. Many river basins throughout Asia are already extracting water in a way that is not sustainable in the long term. “Sustainable” abstraction of groundwater can be set in relation to long-term balance between recharge and abstraction and the economic cost of pumping water from an aquifer. In the Hai River Basin, net water withdrawals have consistently exceeded annual replenishment, resulting in rapidly falling water levels. The prime target of water accounting (and its associated allocation processes) in this basin is to bring water use within sustainable limits, principally through: (1) reducing agricultural use of groundwater through quotas and, in some cases, through land retirement; and (2) augmenting surface supplies and recharging groundwater with water transferred from the distant Yangtze River.

A key lesson from the Chinese experience in water accounting relates to timing. If a full understanding of the water resource is achieved before scarcity is severe, interventions to address it are easier and less costly to design and implement.

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[43] An SDL is a specific type of cap that is clearly defined by an assessment of a desired ecological state in a river basin, and an accompanying set of environmental water allocations, based on best available science. Earlier CAPs in Australia were defined in terms of limiting license and diversion volumes to the existing status quo, rather than to an SDL.

Water allocation

25. Water accounting is an essential underpinning to transparent and effective water allocation systems. Such systems have been developed in some countries (e.g. Australia, China, France, Iran, United States of America) with varying levels of sophistication and effectiveness. As water scarcity and competition for water resources increases, countries across Asia and the Pacific region need to continually improve the way that they quantify and then allocate their water resources.

26. In principle, it should be relatively easy to identify water users and determine their water use. The main practical difficulty, however, is that users are spread over large areas and their individual usage is not easy to measure and monitor. Water economies therefore remain largely "informal" and outside of state control.[44]

27. Governments have often taken ownership of water and given rights to use water (entitlements) to their citizens. In some countries, the specification of those rights is absolute (e.g. under the prior appropriation doctrine in the United States of America) and in others it is proportional to the water available in any year and is based on "equal sharing" of available water resources (e.g. Australia).

28. In developed countries, water rights are often specified on an individual basis for agricultural users. Given the large numbers of farmers and correspondingly small areas of land per farm in Asia, this is a gargantuan task of administration. In some countries, such as Australia and China, a higher level of water entitlement is defined for whole irrigation systems, cities, rural towns and administrative units, although industrial entitlements tend to be individual. This bulk entitlement is usually defined as the sum of all individual entitlements (if they exist) or an estimate of water users' water requirements plus the volume of water needed to operate a system to deliver to all users.

29. Where water rights systems exist and have been developed, it should be simpler to measure and define actual water use and to predict needs. In most countries in Asia, water has historically been thought to be abundant, formal water rights systems have rarely been developed and, in many cases, traditional "customary" rights have been lost.

Assessing and strengthening water institutions

30. Water accounting alone is not sufficient to drive the required shifts in water use as scarcity worsens. Accounting must be accompanied by regular assessments of governance, institutions, public and private expenditure, legislation and the wider political economy of water. In the literature, these assessments have been called water audits (a term that is not always well understood). In practice, this process should: (1) have high-level stakeholder engagement; (2) be inclusive in terms of gender and marginalized social groups; (3) recognize environmental flows; and (4) aim to protect rare and/or important aquatic ecosystems.

31. Water audits/institutional assessments should aim to develop effective and evidence-based policies and to strengthen mechanisms that enforce decisions and use penalties where required.

32. FAO has developed a rough sequencing of steps involved in creating mutually supportive water accounting and auditing:[45]

a. Conduct a preliminary stakeholder analysis at the start of an adaptive and cyclical process.

b. Build rapport with key stakeholders by: (1) identifying specific needs and expectations from adopting and using water accounting and auditing; and (2) delineating and specifying the temporal and spatial boundaries and scale of a cycle of rapid water accounting.

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[44] Shah, T.S., 2007. Ch.5 Issues in Reforming Informal Water Economies of Low-income Countries: 65 Examples from India and Elsewhere in Community-based Water Law and Water Resource Management Reform in Developing Countries in CAB International (eds B. van Koppen, M. Giordano and J. Butterworth) ISBN 978-1-84593-326-5

[45] Batchelor, C. 2019. Commentary on FAO Methodology for Water Audit Version 1, September 6, 2019. pers.comm.

c. Plan and implement a rapid cycle of water accounting and auditing with aims that include: (1) building teams; (2) assessing the capacity-building needs of teams and team members; (3) engaging with stakeholders to determine priority biophysical and societal challenges; (4) assessing the accessibility of relevant secondary data; (5) evaluating and, if relevant, building on existing knowledge and practices; and (6) planning a second cycle of more detailed water accounting and auditing.

d. Perform subsequent cycles of water accounting and auditing aimed at: (1) filling gaps in available data; (2) reducing uncertainties in outputs; and (3) building stakeholder confidence in, and ownership of, outputs.

33. Malaysia is a good example of a country in the region which has invested in improving national water accounting and auditing processes. Although Malaysia has abundant water resources, it experiences seasonal water stress. River basin planning and management is well established in seven basins and the country, and Malaysia is embarking on a serious effort to establish effective water accounting and develop a formal water allocation system under its 12th National Development Plan.[46] It already has established a National Water Balance System[47] that has been implemented using hydrological and other computer models in the granary regions of the country.

Allocating water to the environment

34. A key objective of water accounting, auditing and allocation should be to ensure sufficient water for the vital ecosystem services that underpin sustainable food systems. However, provisions for effective environmental water management are weak throughout the region. China has demonstrated new and innovative efforts in this regard with its “Ecological Red Lines” policy that contains targets to restore river and other aquatic water quality and ecological function across the entire country.[48] However, in most countries environmental water allocation is considered at best to be a residual use after anthropogenic demands – and agricultural ones in particular – have been satisfied. South Africa established strong environmental controls and targets in its seminal water law, but there has been disappointment with its implementation in the succeeding 20 years.[49] Regulatory and environmental oversight have been formally established in Thailand (by the Office for National Water Resources) and in Viet Nam (by the Ministry of Natural Resources and Environment), but many practical challenges remain in balancing sustainable and effective ecosystem management with irrigation in a harmonious manner. The region is still in need of a good role model for ecologically sensitive water management.

Agriculture sector responses to declining water allocations: producing more food with less water

Sustainable food production and water use

35. Regardless of how broad-scale water governance and water allocation are implemented, irrigated agriculture in Asia will need to adapt to declining water availability while maintaining and improving productivity. Food security will continue to be a major political and policy concern for governments,

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[46] Adi, A. 2019. MCID, translation of section G - water transformation of RMK 12 (12th National Development Plan): pers. comm.

[47] Husain, R., Ishak, A.M., Redzuan, N., van Kalken, T.M. & Brown, K. 2017. Malaysian National Water Balance System (NAWABS) for Improved River Basin Management: Case Study in The Muda River Basin. Proceedings of the 37th IAHR World Congress, August 13–18, 2017, Kuala Lumpur, Malaysia.

[48] China Water Risk 16 April 2015. China’s most comprehensive water policy to date, which will ultimately transform China’s environment & economy. http://www.chinawaterrisk.org/notices/new-water-ten-plan-to-safeguard-chinas-waters/

[49] The Conversation, February 6, 2018. South Africa needs good water management - not new water laws. https://theconversation.com/south-africa-needs-good-water-management-not-new-water-laws-91253

but as urbanization and industrialization proceed apace, the ability to supply all food requirements domestically will be constrained, and some broader policy shifts will follow.

Managing and enhancing water supply

36. Traditionally, supply-side management of water demand provides better access to groundwater or to surface water through dam storage, interbasin transfer or other infrastructure improvements, such as canal modernization. Water use therefore increases and may, in turn, cause water scarcity. Where water scarcity already exists (i.e. in a closed river basin), enhancing supply in one part of a river basin or catchment will reduce water security to existing downstream users. Where water abstraction is already high, the challenge in implementing supply-side solutions is to be sure that they will not exaggerate water scarcity and competition for water. This is one of the main reasons why effective water accounting and allocation are needed.

Interbasin transfers

37. Supply-side options to managing water scarcity (such as the south-north interbasin transfer of 20 billion cubic metres annually from the Yangtze river to the North China Plain) have multiple objectives: (1) secure urban and industrial supplies; (2) take pressure off aquifers; and (3) possibly substitute for some agricultural groundwater use.

38. There are clearly many costs and externalities attached to large-scale interbasin transfer, but *in extremis*, there are sometimes few practical alternatives.[50] Increased use of surface storage (in reservoirs) can improve the timing, flexibility and therefore productivity of limited supplies and can provide interannual water security in varying climates, usually at some considerable cost to aquatic ecosystems.[51] Surface storage is usually more vulnerable to climate change than groundwater because of the direct effects of increased variability in rainfall duration and intensity and in catchment yield.[52] There has been considerable interest in managed aquifer recharge as a way of enhancing groundwater storage.[53] Although, in principle, the robustness of groundwater storage is attractive compared with surface storage, its vulnerability to overdraft and poor governance undermines this potential.

Wastewater reuse

39. In response to rapid urbanization and a significant lag in sanitation and water treatment, there has been an explosion in the use of wastewater, particularly by peri-urban farmers.[54] It is effectively a reuse of non-consumptive allocation for drinking, industrial and sanitation purposes, with a considerable downside for water quality and public health. While volumes can be significant in a local sense, they are unlikely to be a large portion of total beneficial water use when urban and industrial use only accounts for 5-10 percent of diverted water use. However, where this balance has changed significantly (as in China) and 40 percent or more of water use is for cities and industry, then

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[50] Shao, X., Wang, H., & Wang, Z. 2003. Interbasin transfer projects and their implications: A China case study, International Journal of River Basin Management, 1:1, 5-14, DOI: 10.1080/15715124.2003.9635187

[51] Hughes, A. C. 2017. Understanding the drivers of Southeast Asian biodiversity loss. Ecosphere 8(1): e01624. 10. 1002/ecs2.1624

[52] Faures, J.M., Svendsen, M., and Turral, H.N. 2007. Irrigation Impacts. Ch.9 Comprehensive Assessment of Water Management in Agriculture. Earthscan. ISBN 978-1-84407-396-2

[53] Casanova J., Devau N., Pettenati, M. 2016. Managed Aquifer Recharge: An Overview of Issues and Options. In: Jakeman, A.J., Barreteau, O., Hunt, R.J., Rinaudo, JD., Ross, A. (eds) Integrated Groundwater Management. Springer, Cham 978-3-319-23575-2

[54] WWAP (United Nations World Water Assessment Programme). 2017. The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. The United Nations World Water Development Report. Wastewater. The Untapped Resource. Paris: UNESCO. Retrieved from http://unesdoc.unesco.org/images/0024/002471/247153e.pdf

wastewater reuse is a significant opportunity, provided it is carefully managed regarding the challenges described above.[55]

Landscape-level interventions

40. Landscape-level interventions, such as afforestation or improved catchment management, can stabilize water supply and improve water yields under certain conditions. However, intensive upstream catchment development for both rainfed and irrigated cropping can also reduce downstream flows and impact established users.[56] Currently, case studies and accumulated knowledge on landscape management and overall impacts on agricultural water management are limited.

Managing and restraining water demand

41. Responses to water scarcity primarily focus on demand management. It is important to understand that there are only a few means of constraining water demand in agriculture: (1) reducing non-productive evaporation; (2) improving the efficiency of transpiration; (3) reducing net water consumption of crop production systems through modifying crop patterns (crops, varieties and planting dates); and (4) minimizing non-recoverable losses in water delivery systems. Of course, it is possible to reduce the area of irrigated and rainfed crops to reduce water demand, but this results in lost production. However, as climate change and water scarcity worsen, broader-scale reshaping of national agricultural systems becomes increasingly likely, with land retirement in some areas and substitution in others. China, for example, is a large country with varying climatic regions, and so it has been partially successful in relocating wheat production from the water-stressed North China Plain to wetter, lower-demand areas north of the Yangtze River.[57]

42. Thus, the key response to static or declining water availability for agriculture because of intersectoral water transfer is to produce more food with less water, in essence, to improve water productivity, at the farm level, system/catchment and national levels. Many of the techniques proposed for climate-smart irrigation and climate-smart agriculture can be applied in managing water scarcity.[58]

Improved agronomic practices

43. Agricultural water productivity can be increased in three ways: (1) decreased water use with the same level of production; (2) increased production with same level of water use; and (3) increased production with decreased water use (the ultimate goal). There is considerable variation in the water and land productivities achieved by individual farmers within the same farming system and conditions. High-level crop productivity, although strongly correlated to water use in ideal conditions, is dependent on the optimal combination of all factor inputs (including soil characteristics, nutrition, solar radiation, water use, weed control, plant health, education level of the farmer and the timing and quality of field operations and agronomic practice) and their interactions (especially water and nitrogen fertilizer). Significant gains can be made by bridging the gaps between potential levels (i.e. best practice) and typical levels of water productivity, providing the reasons can be identified and addressed.[59]

Plant breeding

44. At the next level, increased yield and water productivity of staple crops in Asia (e.g. rice, wheat,

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[55] Damania, R., Desbureaux, S., Rodella, A.S., Russ, J., & Zaveri, E. 2019. Quality Unknown: The Invisible Water Crisis. Washington, DC: World Bank. doi:10.1596/978-1-4648-1459-4. License: Creative Commons Attribution CC BY 3.0 IGO

[56] Calder, I., Gosain, A., Rama Mohan Rao, MS., Batchelor, C., Garratt, J., & Bishop, E. 2007. Watershed development in India. New approaches for managing externalities and meeting sustainability requirements. Environ Dev Sust DOI 10.1007/s10668-006-9073-0

[57] IWHR, Pers. Comm. and internal presentation. September 2019

[58] Batchelor, C. & Schnetzer, J. 2018. Compendium of climate-smart irrigation. GACSA/FAO. Rome. www.fao.org/gacsa/en/.

[59] Perry, C. & Steduto, P. 2017. "Does Improved Irrigation Technology Save Water? A Review of the Evidence." Discussion paper on irrigation and sustainable water resources management in the Near East and North Africa. Regional Initiative on Water Scarcity for the Near East and North Africa. Cairo, FAO.

maize) have historically been influenced by crop breeding for an increased harvest index, tolerance to short-term drought or water logging, and selection of high-yielding (nitrogen-responsive) varieties. Step changes in productivity have been achieved with the introduction of hybrid rice in China and subsequently elsewhere.

Increasing the efficiency of irrigation supply networks

45. There are good reasons to increase the efficiency of transmission of irrigation networks (by lining canals, for example). Increasing transmission efficiency can improve management, make more land available for farming, increase the quality of service and reduce externalities, such as water logging and salinity. However, to achieve real water savings through efficiency measures, there has to be a measurable reduction in: (1) evaporation loss, which is mostly only achievable if canals are converted to pipes; and (2) non-recoverable seepage and leakage losses, which might occur (a) as waterlogging and subsequent non-productive evaporation, as in Sindh, Pakistan;[60] (b) through accession to saline groundwater, as in many parts of China, northern India and Pakistan. The absolute volumes saved through minimizing evaporation losses are generally small, but they can be significant in terms of non-recoverable return flows in specific locations.

46. At the field level, improved irrigation uniformity and efficiency have benefits for crop condition and production and may result in reduced non-productive evaporation and non-recoverable seepage and return flows, if there is saline shallow groundwater or adjacent waterlogging.[61] Techniques such as micro-irrigation can certainly reduce non-productive evaporation, but unless water quotas/allocations/deliveries are reduced correspondingly, the “saved” water is likely to be used in locally beneficial transpiration.[62] Determination of real, allocable water savings depends on knowing the fate of losses, whether they were re-used (where and by whom) and if not, whether they are physically recoverable for use elsewhere. Therefore, it is important to be able to evaluate the impacts of local water-savings efforts on the achievement of real water savings at system, catchment, river basin and national scales.

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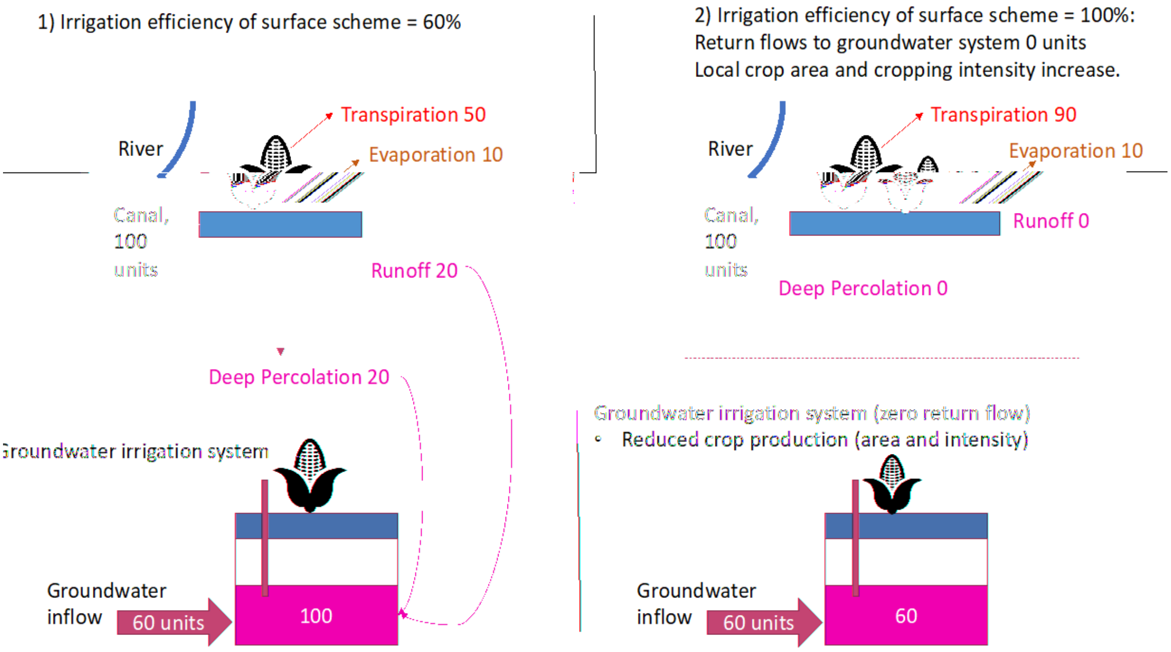
[60] Molden, D., Murray-Rust, H., Sakthivadivel, R. & Makin, I. 2003. A water- productivity framework for understanding and action. In: Kijne, J.W., Barker, R., Molden, D. (Eds). *Water productivity in agriculture: Limits and opportunities for improvement.* Wallingford, IWMI & CABI Publishing, pp. 1–18.

[61] Turral, H. & Wood, M. 2013. Review of Irrigation Modernisation in Australia, World Bank, Washington.

[62] Perry, C. & Steduto, P. 2017. “Does Improved Irrigation Technology Save Water? A Review of the Evidence.” Discussion paper on irrigation and sustainable water resources management in the Near East and North Africa. Regional Initiative on Water Scarcity for the Near East and North Africa. Cairo, FAO.

Irrigation efficiency: winners and losers at basin scale

To explain the conundrum that improving efficiency does not necessarily save water and may actually increase water use where the efficiency measures are applied, consider a simple illustrative case of a small surface irrigation system with low (50 percent) efficiency (Situation 1). The return flows contribute to aquifer supplies available to farmers in a downstream groundwater district. The groundwater available to those farmers consists of natural inflows to the aquifer from connected upstream aquifers, plus the return flows from the surface irrigation district which are originally sourced from the river.



When a high irrigation efficiency technology (e.g. drip tape) is applied in the surface irrigation area (Situation 2), all percolation and runoff return flows to the groundwater irrigation district cease. Groundwater-dependent farmers can access less water and therefore they produce less. Meanwhile, farmers in the surface irrigation system find they have more water available, and so they increase their cropped area or change their crop pattern, or both, in order to profit from the available water.

If canal flows to the surface irrigation area are reduced to 50 units so that they consume no more than before, or if there are strict quotas/licenses in place so that water consumption will remain as before, there is still a need to restore 50 units to the downstream groundwater users.

Clearly the real world is more complex and the numbers more complicated, but the general principle is well illustrated in this simple and idealized case.

Water pricing

47. Water charges can (and indeed should) be used to ensure the financial sustainability of irrigation systems and associated water management. If related directly to the volume of water delivered (which is rare in Asia), charges can also encourage a reduction in demand. However, there is little practical evidence that pricing rates are high enough to generate any substantial water saving anywhere in Asia. If the objective is to achieve sustainable levels of use, the evidence from the literature and the field is that even the level of charges required simply to meet operation and maintenance costs are politically

infeasible.[63] No country in Asia applies water charges to irrigated agriculture in order to balance demand and sustain supply—everywhere, the primary means of achieving a balance is setting physical quotas usually related to area and crop type. Where such quotas are tradable, local informal market prices can emerge in the form of rents on borehole use, for instance. The secularly declining terms of trade for smallholder farmers in Asia compromises both their ability and willingness to pay water tariffs, and many farmers are wary of area-based taxes because of the high levels of rent-seeking involved in their collection. At present, there is little understanding of how to price water in order to limit the amount consumed compared with the amount supplied.

Water management involves more than water

Digital innovation

48. Non-traditional innovations in agriculture are expected to change food production systems in the future. There are great expectations for the use of information and communication technologies in farming and food distribution to improve production, productivity and marketing through precision farming and logistics. Close-range remote sensing using drones is already a practical and cost-effective possibility for commercial farmers in the OECD,[64] and their use will likely spill over to other regions as the structure of farming changes, the numbers of active farmers decline and land holdings consolidate under leasing or changed ownership, encouraging economies of scale and increasing the possibilities for capital investment. More intensive soil and vegetation monitoring in a variety of forms will contribute to reducing productivity gaps and optimizing total factor productivity for sustainable agriculture.[65]

Innovative production environments

49. More contentious, cutting-edge innovations include closed-cycle growing rooms, modified greenhouses/shade houses, and vertical farming systems in urban settings with closed water cycle modules which are currently energy intensive because of the use of artificial “photosynthetic” lighting.[66] Such innovations are more likely to be cost-effective in niche (close to market, high value) production, but at the moment they will make little impact on agricultural water use in general. They may become increasingly important in high-density urban conditions, including those in Asia.[67]

50. There are a number of interventions outside farming that could lead to substantial water savings, including substitutes for meat that include insect protein and synthetically “grown” meat, both of which are in the early stages of commercial development. How far such alternatives penetrate into markets, and especially into lower-cost ones in Asia, remains to be seen.

Food policies

51. Food policies, especially national food pricing and subsidy policies, affect decisions taken by farmers on which crops to grow. This is because they influence incentive structures which, in turn, can affect water-provision policies. For example, in water-scarce Pakistan and the Indian Punjab, farmers still opt to grow water-intensive rice and wheat because they receive high prices resulting from

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[63] Molle, F., & Berkoff, J. 2007. Irrigation water pricing: The gap between theory and practice. Comprehensive Assessment of Water Management in Agriculture. https://doi.org/10.1079/9781845932923.0000

[64] PrecisionHawk, Drone-based Aerial Intelligence in Precision Agriculture, Commercial Brochure. 20 pp. https://www.precisionhawk.com/hubfs/PrecisionHawk%20PrecisionAnalytics%20Agriculture%20Solution%20Brief%202019.pdf, accessed 2019 10 03.

[65] PrecisionHawk, Drone-based Aerial Intelligence in Precision Agriculture, Commercial Brochure. 20 pp. https://www.precisionhawk.com/hubfs/PrecisionHawk%20PrecisionAnalytics%20Agriculture%20Solution%20Brief%202019.pdf, accessed 2019 10 03.

[66] UBS. 2019. The food revolution: the future of food and the challenges we face. Chief Investment Office GWM Investment Research Version 05/2019. CIO82652744 © UBS 2019

[67] Harringron, P., Lacewell, D. & Taylor, C. 2015. Non-traditional Agriculture: Path to Future Food Production? Texas Water Resources Institute Technical Report TR-483 December 2015

government food procurement policies.[68] Electricity subsidies also contribute to overexploitation of groundwater.

Reducing food loss and waste and altering diets

52. Reducing post-harvest food loss and waste is a legitimate strategy to address water scarcity. FAO estimates that food loss and waste between the field and end users is up to 30 percent, with losses occurring during harvesting, transportation, storage and packaging, food processing, wholesale and retail trade and in households.[69] A shift towards less water-intensive diets can also play a role, as calories derived from animal products require from 4 to 16 times more water to produce than those derived from vegetable products.[70]

International trade in virtual water

53. Once supply- and demand-side interventions are exhausted, it becomes necessary to lower water-use intensity in regions where water is scarce by optimizing virtual water flows from regions with plentiful water supplies to those that experience shortage.[71] This will not be easy. Increasing national reliance on global food markets is highly politically unpalatable in many countries. Additionally, many people in Asia still depend on agriculture for their livelihoods, and viable alternatives will be needed to avoid driving farmers into poverty.[72] Before relying on the international market to help address water scarcity in agriculture, investments are needed in comprehensive and strategic regional development policies that fully elaborate the trade-offs regarding economic growth, livelihoods, environmental degradation and food security.[73]

FAO Water Scarcity Programme for Asia and the Pacific Region (2020-2023)

54. FAO in Asia and the Pacific region is establishing a Water Scarcity Programme (WSP) in cooperation with Members and is in the process of designing a new framework for practical support. The overarching objective of the WSP is to bring agricultural water use to within sustainable limits and prepare the sector for a productive future with less water. This objective requires sustained effort at regional, country and local levels.

55. Between 2020 and 2023, the WSP will assess the scope of water scarcity, evaluate effective management response options, work to improve governance and assist partner countries to implement adaptive management in the agriculture water sector using appropriate and newly developed tools and methodologies. The WSP will revamp existing tools in addition to developing new tools and approaches that fully utilize modern technologies (e.g. remote sensing by satellite, mobile applications, modelling frameworks, promotion of citizen science). New or revamped technologies and tools on water accounting and water allocation will be contextualized in target countries. Working closely with national decision-makers, the WSP will also develop associated training modules and programmes to help ensure new approaches are implemented in practice. In addition, all new products will be scaled and refined via ongoing and new FAO programming – in particular through the growing Global Environment Facility, Green Climate Fund and World Bank-FAO Cooperative programmes.

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[68] Mukherji, A., Facon, T., Burke, J., Fraiture, C. de, Faurès, J.-M., Füleki, B., Shah, T., *et al.* 2009. Revitalizing Asia’s irrigation: to sustainably meet tomorrow’s food needs. Colombo, Sri Lanka: IWMI, FAO.

[69] FAO. 2011. Global food losses and food waste - Extent, causes and prevention. SAVE FOOD: An initiative on Food Loss and Waste Reduction. https://doi.org/10.1098/rstb.2010.0126

[70] Jalava, M., Kummu, M., Porkka, M., Siebert, S., & Varis, O. 2014. Diet change - A solution to reduce water use? Environmental Research Letters, 9(7). https://doi.org/10.1088/1748-9326/9/7/074016

[71] Kummu, M., Ward, P. J., De Moel, H., & Varis, O. 2010. Is physical water scarcity a new phenomenon? Global assessment of water shortage over the last two millennia. Environmental Research Letters, 5(3). https://doi.org/10.1088/1748-9326/5/3/034006

[72] Faures, J.M., Svendsen, M., and Turral, H.N. 2007. Irrigation Impacts. Ch.9 Comprehensive Assessment of Water Management in Agriculture. Earthscan. ISBN 978-1-84407-396-2

[73] White, D. J., K., H., Feng, K., Sun, L., & Meng, B. 2017. The Water-Energy-Food Nexus in East Asia: A Tele-connected Value Chain Analysis Using Inter-Regional Input-Output Analysis. Journal of Applied Energy

56. Specific WSP components include:

a. Strengthening country capacity to conduct water accounting to quantify scarcity and better understand the factors influencing water scarcity. Activities include:

   i. Training water professionals and decision-makers in countries to conduct regular and progressively more detailed and accurate water accounts and make appropriate adjustments to governance to promote a formal water allocation process.

   ii. Promoting and refining the use of remote sensing to determine consumptive use and as many components of water balance as possible in order to complement and substitute for scarce data.

   iii. Developing new, simple-to-use tools to help countries assess water balance, water use, current and future water demand, and the hydrologic impacts of field interventions at the basin scale.

- The key expected outputs are:

   i. Common information bases in selected countries that are acceptable to all the primary stakeholders involved in planning or other decision-making processes.

   ii. A water accounting capacity which is embedded in the institutional arrangements for water resources management and planning in selected countries.

   iii. A manual of real water-saving and water productivity-enhancing practices and a spreadsheet tool to evaluate their impact at various scales.

b. Strengthening policy and governance mechanisms, including coherence with key policies on food, energy, industry and environment. Particular focus is on water quality, ecosystem needs and climate change (drought management). Activities include:

   i. Conducting a regional geospatial assessment of water scarcity.

   ii. Developing focal country water-scarcity profiles, including management responses and their effectiveness, as well as an assessment of water-modelling capacity through the region.

   iii. Producing a regional synthesis report that consolidates best practices from across the region and identifies entry points and pathways for countries to progress in tackling water scarcity.

- The key expected outputs are:

   i. A regional synthesis report on water scarcity and the governance arrangements for managing it, with a particular focus on groundwater-surface water and water quality interactions.

   ii. A regional synthesis report and diagnosis of water modelling capacity and requirements for strengthening the implementation of water accounting and water allocation processes.

   iii. At least two country water-scarcity management strategies, developed and agreed upon with a wide range of stakeholders.

c. Providing the knowledge, capacity and expertise needed for countries to take action. Activities include:

  i. Sharing new knowledge products on proven options for improving productive agricultural water management in the face of increasing scarcity and the achievement of real water savings.

  ii. Conducting scenario exercises to help governments think about emerging allocation, reallocation options and adaptive measures in agricultural water management.

  iii. Establishing a new regional platform to facilitate the exchange of knowledge and best practices within and between countries across Asia and the Pacific region.

- The key expected outputs are:

  i. South-South training and a capacity-building programme in water resources modelling established in at least three recipient countries.

  ii. A high-level regional consultation on managing and adapting to water scarcity to be held during the last quarter of 2021.

  iii. A regional high-level collaborative platform on water scarcity, potentially subdivided into subregions where settings, and challenges are common (e.g. South Asia, East Asia, Southeast Asia and the Pacific).

57. New tools, knowledge and lessons learned throughout the implementation of the WSP will be used to strengthen all FAO programming in the region, including fast-growing programmes and projects with the Global Environment Facility and the Green Climate Fund. These projects present an excellent opportunity to upscale the results and increase overall impact.