Water Resources Engineering 3rd edition Mays Solutions Manual

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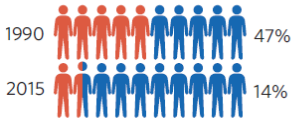
Chapter 2

2.1.1 The UN Millennium Development Goals (MDG) 2015 Report discusses the achievements made since the Millennium Development Goals adopted in September 2000. Define these achievements by going to the MDG 2015 Report.

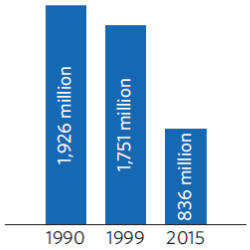
Solution

GOAL 1: ERADICATE EXTREME POVERTY AND HUNGER

Extreme poverty rate in developing countries



Global number of extreme poor

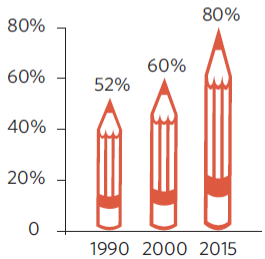


- Extreme poverty has declined significantly over the last two decades. In 1990, nearly half of the population in the developing world lived on less than $1.25 a day; that proportion dropped to 14 per cent in 2015.
- Globally, the number of people living in extreme poverty has declined by more than half, falling from 1.9 billion in 1990 to 836 million in 2015. Most progress has occurred since 2000.
- The number of people in the working middle class—living on more than $4 a day—has almost tripled between 1991 and 2015. This group now makes up half the workforce in the developing regions, up from just 18 per cent in 1991.
- The proportion of undernourished people in the developing regions has fallen by almost half since 1990, from 23.3 per cent in 1990–1992 to 12.9 per cent in 2014–2016.

GOAL 2: ACHIEVE UNIVERSAL PRIMARY EDUCATION

Global out-of-school children of primary school age

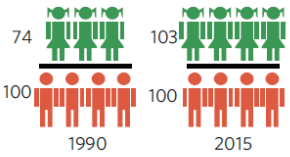
Primary school net enrolment rate in sub-Saharan Africa



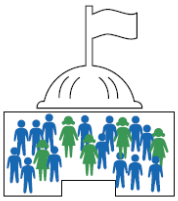
- The primary school net enrolment rate in the developing regions has reached 91 per cent in 2015, up from 83 per cent in 2000.
- The number of out-of-school children of primary school age worldwide has fallen by almost half, to an estimated 57 million in 2015, down from 100 million in 2000.
- Sub-Saharan Africa has had the best record of improvement in primary education of any region since the MDGs were established. The region achieved a 20 percentage point increase in the net enrolment rate from 2000 to 2015, compared to a gain of 8 percentage points between 1990 and 2000.
- The literacy rate among youth aged 15 to 24 has increased globally from 83 per cent to 91 per cent between 1990 and 2015. The gap between women and men has narrowed.

GOAL 3: PROMOTE GENDER EQUALITY AND EMPOWER WOMEN

Primary school enrolment ratio in Southern Asia



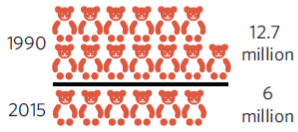
90% of countries have more women in parliament since 1995



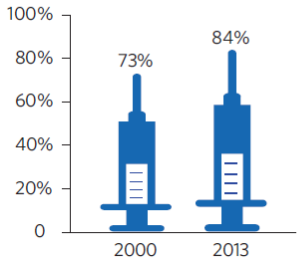
- Many more girls are now in school compared to 15 years ago. The developing regions as a whole have achieved the target to eliminate gender disparity in primary, secondary and tertiary education.
- In Southern Asia, only 74 girls were enrolled in primary school for every 100 boys in 1990. Today, 103 girls are enrolled for every 100 boys.
- Women now make up 41 per cent of paid workers outside the agricultural sector, an increase from 35 per cent in 1990.
- Between 1991 and 2015, the proportion of women in vulnerable employment as a share of total female employment has declined 13 percentage points. In contrast, vulnerable employment among men fell by 9 percentage points.
- Women have gained ground in parliamentary representation in nearly 90 per cent of the 174 countries with data over the past 20 years. The average proportion of women in parliament has nearly doubled during the same period. Yet still only one in five members are women.

GOAL 4: REDUCE CHILD MORTALITY

Global number of deaths of children under five



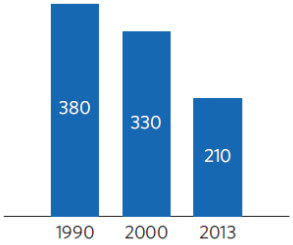
Global measles vaccine coverage



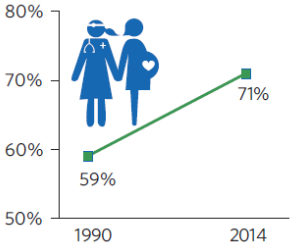
- The global under-five mortality rate has declined by more than half, dropping from 90 to 43 deaths per 1,000 live births between 1990 and 2015.
- Despite population growth in the developing regions, the number of deaths of children under five has declined from 12.7 million in 1990 to almost 6 million in 2015 globally.
- Since the early 1990s, the rate of reduction of under-five mortality has more than tripled globally.
- In sub-Saharan Africa, the annual rate of reduction of under-five mortality was over five times faster during 2005–2013 than it was during 1990–1995.
- Measles vaccination helped prevent nearly 15.6 million deaths between 2000 and 2013. The number of globally reported measles cases declined by 67 per cent for the same period.
- About 84 per cent of children worldwide received at least one dose of measles-containing vaccine in 2013, up from 73 per cent in 2000.

GOAL 5: IMPROVE MATERNAL HEALTH

Global maternal mortality ratio (deaths per 100,000 live births)



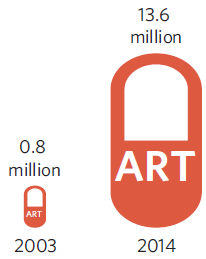
Global births attended by skilled health personnel



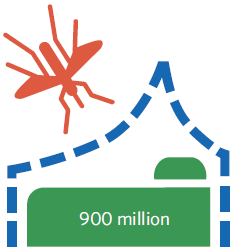
- Since 1990, the maternal mortality ratio has declined by 45 per cent worldwide, and most of the reduction has occurred since 2000.
- In Southern Asia, the maternal mortality ratio declined by 64 per cent between 1990 and 2013, and in sub-Saharan Africa it fell by 49 per cent.
- More than 71 per cent of births were assisted by skilled health personnel globally in 2014, an increase from 59 per cent in 1990.
- In Northern Africa, the proportion of pregnant women who received four or more antenatal visits increased from 50 per cent to 89 percent between 1990 and 2014.
- Contraceptive prevalence among women aged 15 to 49, married or in a union, increased from 55 per cent in 1990 worldwide to 64 per cent in 2015.

GOAL 6: COMBAT HIV/AIDS, MALARIA AND OTHER DISEASES

Global antiretroviral therapy treatment



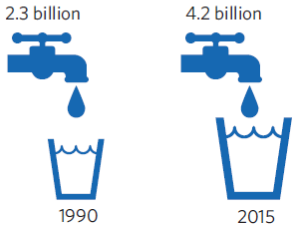
Number of insecticide-treated mosquito nets delivered in sub-Saharan Africa, 2004–2014



- New HIV infections fell by approximately 40 per cent between 2000 and 2013, from an estimated 3.5 million cases to 2.1 million.
- By June 2014, 13.6 million people living with HIV were receiving antiretroviral therapy (ART) globally, an immense increase from just 800,000 in 2003. ART averted 7.6 million deaths from AIDS between 1995 and 2013.
- Over 6.2 million malaria deaths have been averted between 2000 and 2015, primarily of children under five years of age in sub-Saharan Africa. The global malaria incidence rate has fallen by an estimated 37 per cent and the mortality rate by 58 per cent.
- More than 900 million insecticide-treated mosquito nets were delivered to malaria-endemic countries in sub-Saharan Africa between 2004 and 2014.
- Between 2000 and 2013, tuberculosis prevention, diagnosis and treatment interventions saved an estimated 37 million lives. The tuberculosis mortality rate fell by 45 per cent and the prevalence rate by 41 per cent between 1990 and 2013.

GOAL 7: ENSURE ENVIRONMENTAL SUSTAINABILITY

1.9 billion people have gained access to piped drinking water since 1990

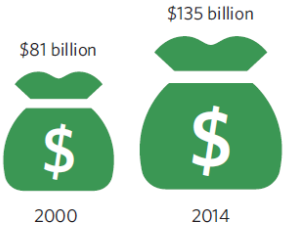


98% of ozone-depleting substances eliminated since 1990

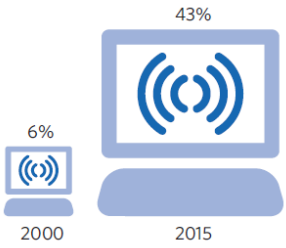
- Ozone-depleting substances have been virtually eliminated since 1990, and the ozone layer is expected to recover by the middle of this century.
- Terrestrial and marine protected areas in many regions have increased substantially since 1990. In Latin America and the Caribbean, coverage of terrestrial protected areas rose from 8.8 per cent to 23.4 per cent between 1990 and 2014.
- In 2015, 91 per cent of the global population is using an improved drinking water source, compared to 76 per cent in 1990.
- Of the 2.6 billion people who have gained access to improved drinking water since 1990, 1.9 billion gained access to piped drinking water on premises. Over half of the global population (58 per cent) now enjoys this higher level of service.
- Globally, 147 countries have met the drinking water target, 95 countries have met the sanitation target and 77 countries have met both.
- Worldwide, 2.1 billion people have gained access to improved sanitation. The proportion of people practicing open defecation has fallen almost by half since 1990.
- The proportion of urban population living in slums in the developing regions fell from approximately 39.4 per cent in 2000 to 29.7 per cent in 2014.

GOAL 8: DEVELOP A GLOBAL PARTNERSHIP FOR DEVELOPMENT

Official development assistance



Global Internet penetration



- Official development assistance from developed countries increased by 66 per cent in real terms between 2000 and 2014, reaching $135.2 billion.
- In 2014, Denmark, Luxembourg, Norway, Sweden and the United Kingdom continued to exceed the United Nations official development assistance target of 0.7 per cent of gross national income.
- In 2014, 79 per cent of imports from developing to developed countries were admitted duty free, up from 65 per cent in 2000.
- The proportion of external debt service to export revenue in developing countries fell from 12 per cent in 2000 to 3 per cent in 2013.
- As of 2015, 95 per cent of the world's population is covered by a mobile-cellular signal.
- The number of mobile-cellular subscriptions has grown almost tenfold in the last 15 years, from 738 million in 2000 to over 7 billion in 2015.
- Internet penetration has grown from just over 6 per cent of the world's population in 2000 to 43 per cent in 2015. As a result, 3.2 billion people are linked to a global network of content and applications.

2.1.2 Despite the successes since the Millennium Development Goals adopted in September 2000 discussed in problem 2.1.1, the poorest and most vulnerable people are being left behind. Discuss this.

Solution from the UN Millennium Development Goals 2015 Report

Although significant achievements have been made on many of the MDG targets worldwide, progress has been uneven across regions and countries, leaving significant gaps. Millions of people are being left behind, especially the poorest and those disadvantaged because of their sex, age, disability, ethnicity or geographic location. Targeted efforts will be needed to reach the most vulnerable people.

xx Gender inequality persists
Women continue to face discrimination in access to work, economic assets and participation in private and public decision-making. Women are also more likely to live in poverty than men. In Latin America and the Caribbean, the ratio of women to men in poor households increased from 108 women for every 100 men in 1997 to 117 women for every 100 men in 2012, despite declining poverty rates for the whole region. Women remain at a disadvantage in the labour market. Globally, about three quarters of working-age men participate in the labour force, compared to only half of working-age women. Women earn 24 per cent less than men globally. In 85 per cent of the 92 countries with data on unemployment rates by level of education for the years 2012–2013, women with advanced education have higher rates of unemployment than men with similar levels of education. Despite continuous progress, today the world still has far to go towards equal gender representation in private and public decision-making.

xx Big gaps exist between the poorest and richest households, and between rural and urban areas
In the developing regions, children from the poorest 20 per cent of households are more than twice as likely to be stunted as those from the wealthiest 20 per cent. Children in the poorest households are four times as likely to be out of school as those in the richest households. Under-five mortality rates are almost twice as high for children in the poorest households as for children in the richest. In rural areas, only 56 per cent of births are attended by skilled health personnel, compared with 87 per cent in urban areas. About 16 per cent of the rural population do not use improved drinking water sources, compared to 4 per cent of the urban population. About 50 per cent of people living in rural areas lack improved sanitation facilities, compared to only 18 per cent of people in urban areas.

xx Climate change and environmental degradation undermine progress achieved, and poor people suffer the most
Global emissions of carbon dioxide have increased by over 50 per cent since 1990. Addressing the unabated rise in greenhouse gas emissions and the resulting likely

impacts of climate change, such as altered ecosystems, weather extremes and risks to society, remains an urgent, critical challenge for the global community. An estimated 5.2 million hectares of forest were lost in 2010, an area about the size of Costa Rica. Overexploitation of marine fish stocks led to declines in the percentage of stocks within safe biological limits, down from 90 per cent in 1974 to 71 per cent in 2011. Species are declining overall in numbers and distribution. This means they are increasingly threatened with extinction. Water scarcity affects 40 per cent of people in the world and is projected to increase. Poor people's livelihoods are more directly tied to natural resources, and as they often live in the most vulnerable areas, they suffer the most from environmental degradation.

xx Conflicts remain the biggest threat to human development

By the end of 2014, conflicts had forced almost 60 million people to abandon their homes—the highest level recorded since the Second World War. If these people were a nation, they would make up the twentyfourth largest country in the world. Every day, 42,000 people on average are forcibly displaced and compelled to seek protection due to conflicts, almost four times the 2010 number of 11,000. Children accounted for half of the global refugee population under the responsibility of the United Nations High Commissioner for Refugees in 2014. In countries affected by conflict, the proportion of out-of-school children increased from 30 per cent in 1999 to 36 per cent in 2012. Fragile and conflict-affected countries typically have the highest poverty rates.

xx Millions of poor people still live in poverty and hunger, without access to basic services

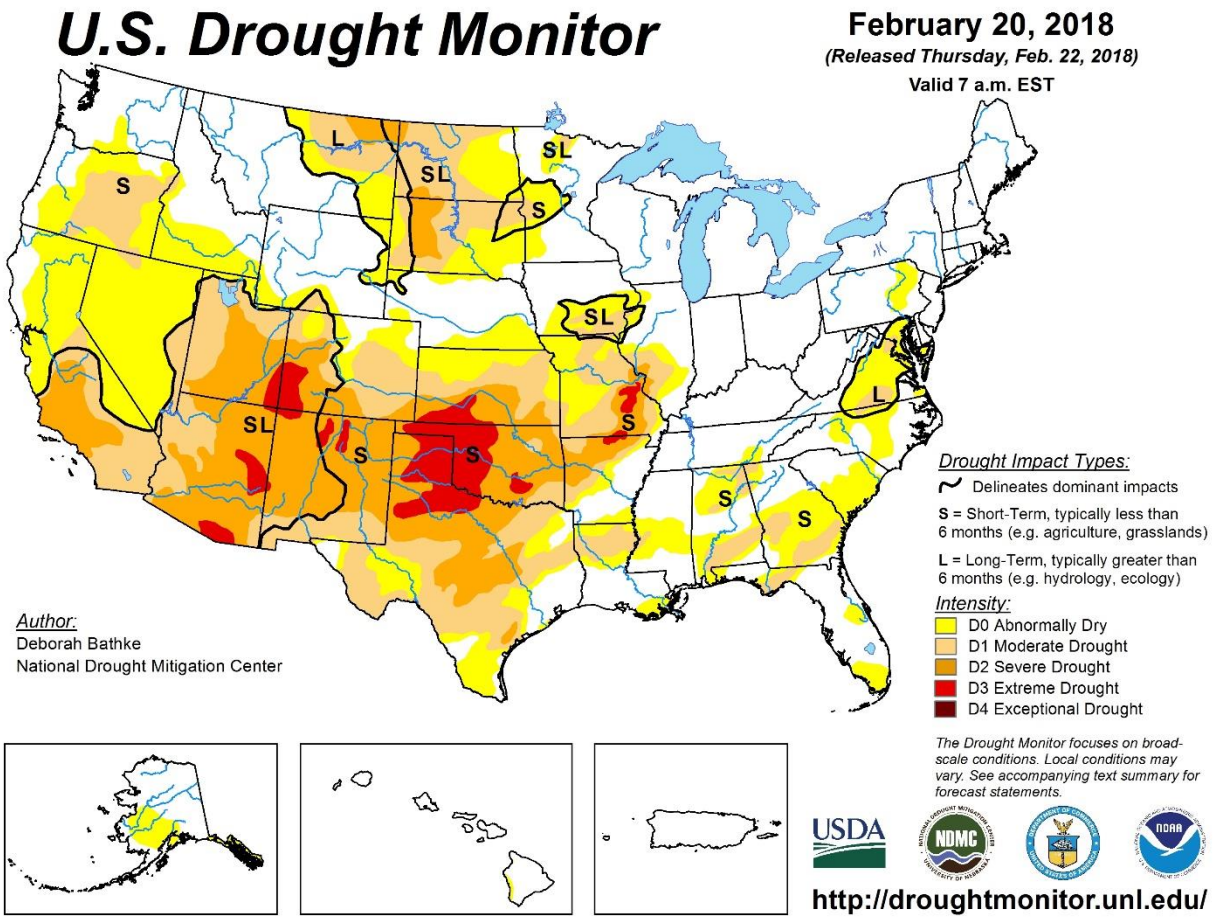
Despite enormous progress, even today, about 800 million people still live in extreme poverty and suffer from hunger. Over 160 million children under age five have inadequate height for their age due to insufficient food. Currently, 57 million children of primary school age are not in school. Almost half of global workers are still working in vulnerable conditions, rarely enjoying the benefits associated with decent work. About 16,000 children die each day before celebrating their

fifth birthday, mostly from preventable causes. The

maternal mortality ratio in the developing regions is 14 times higher than in the developed regions. Just half of pregnant women in the developing regions receive the recommended minimum of four antenatal care visits. Only an estimated 36 per cent of the 31.5 million people living with HIV in the developing regions were receiving ART in 2013. In 2015, one in three people (2.4 billion) still use unimproved sanitation facilities, including 946 million people who still practise open defecation. Today over 880 million people are estimated to be living in slum-like conditions in the developing world's cities. With global action, these numbers can be turned around.

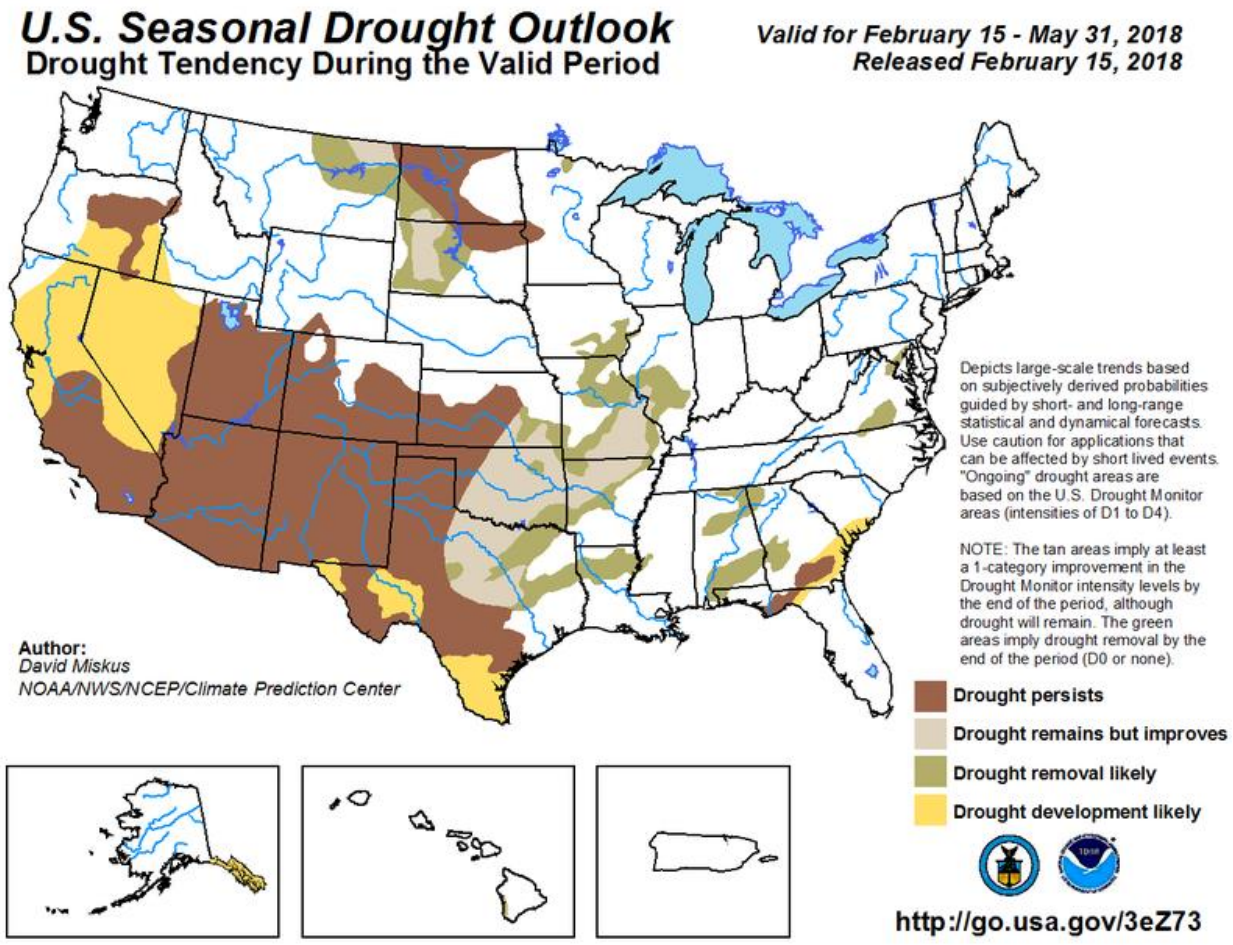
2.2.1 Download the most recent U.S. Drought Monitor and compare to Figure 2.2.5.

Solution: Dependent on date of down load.



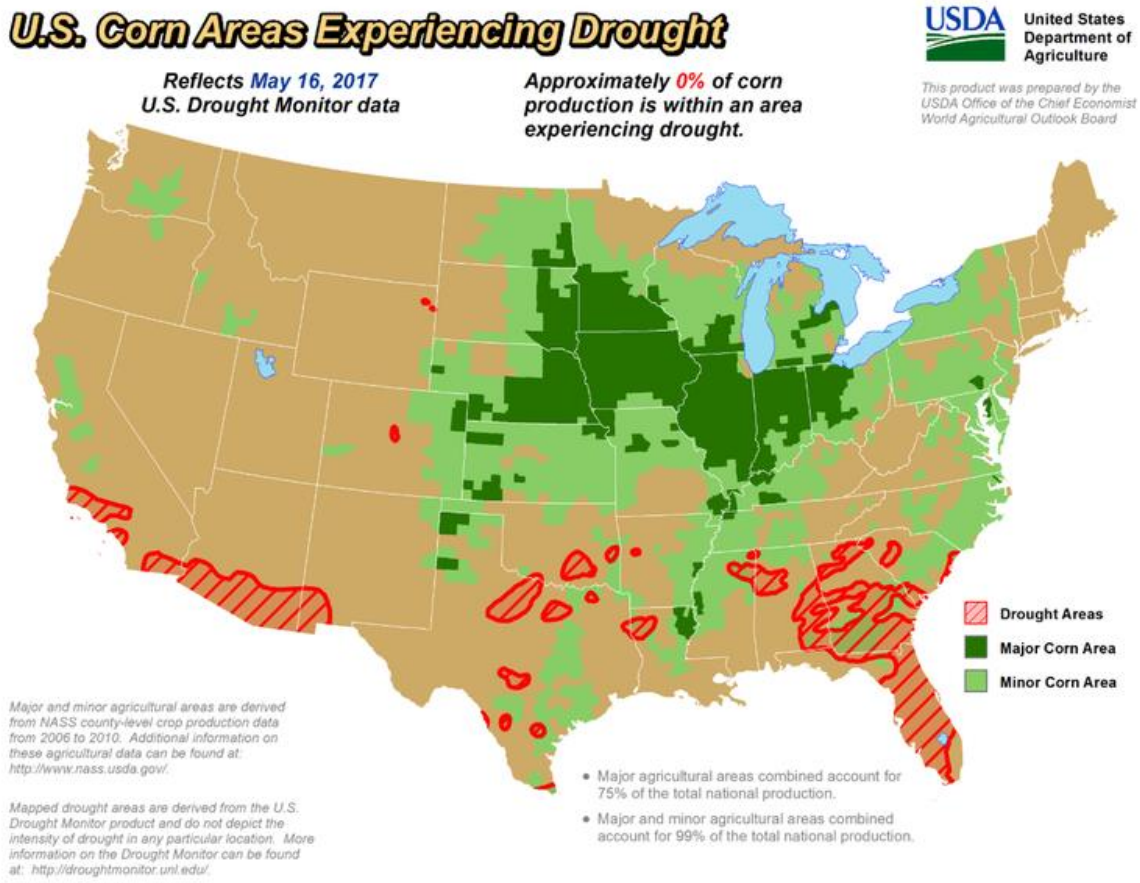
2.2.2 Find the most recent U.S. Seasonal Drought Outlook

Solution: https://www.drought.gov/drought/data-maps-tools/current-conditions



2.2.3 The USDA produces monthly maps and charts displaying locations and percentages of drought-affected areas corn, soybeans, hay, cattle, and winter wheat. Find the U.S. corn areas experiencing drought.

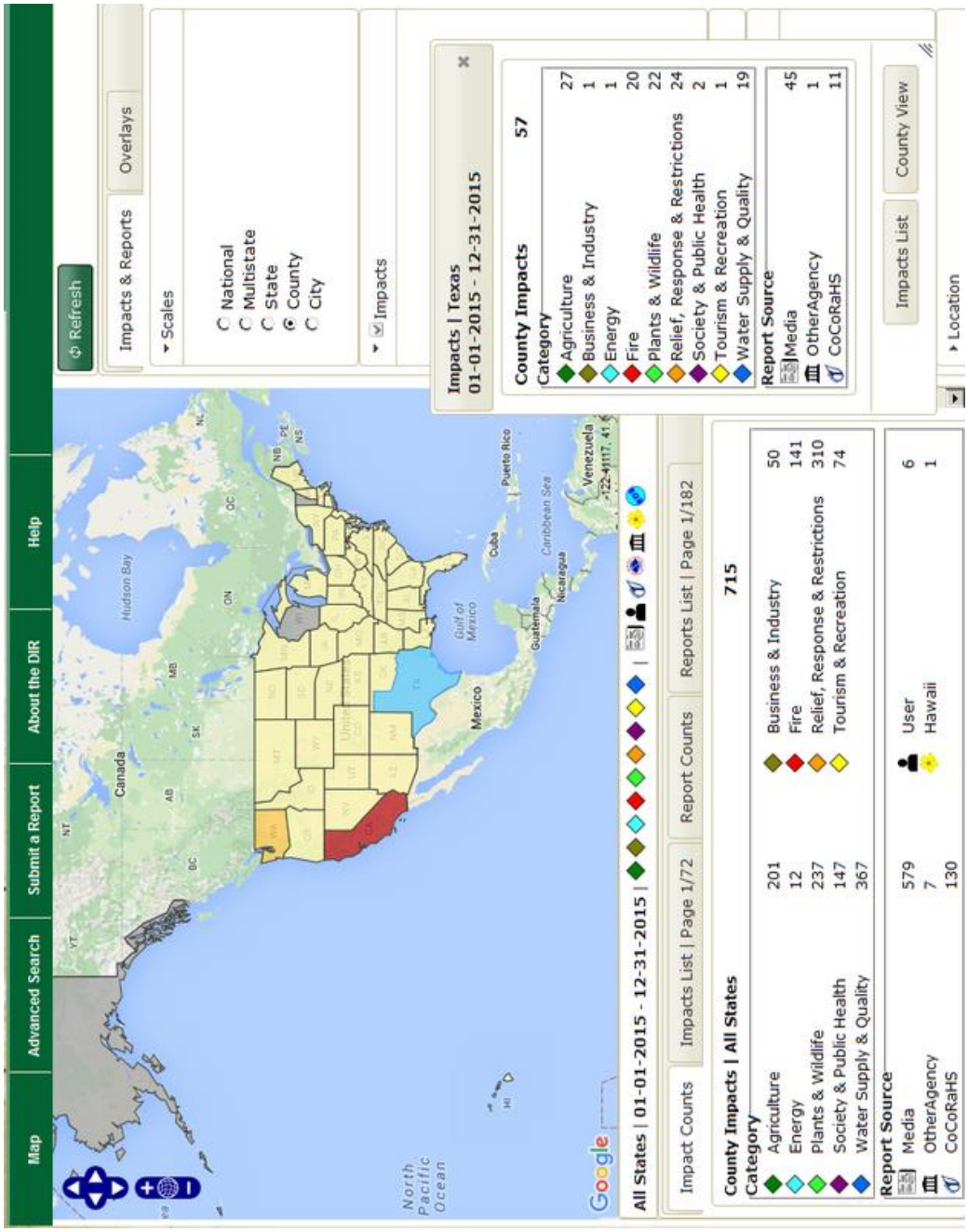
Solution: https://www.drought.gov/drought/data-gallery/us-crops-and-livestock-drought



2.2.4 The Drought Impacts Reporter (DIR) is an interactive database of drought impacts in the U.S., by location, data, type, and cost built from stakeholder, government, media and other reports.

Solution: Data Source: National Drought Mitigation Center (NDMC)
http://droughtreporter.unl.edu/map/

https://www.drought.gov/drought/data-gallery/drought-impact-reporter

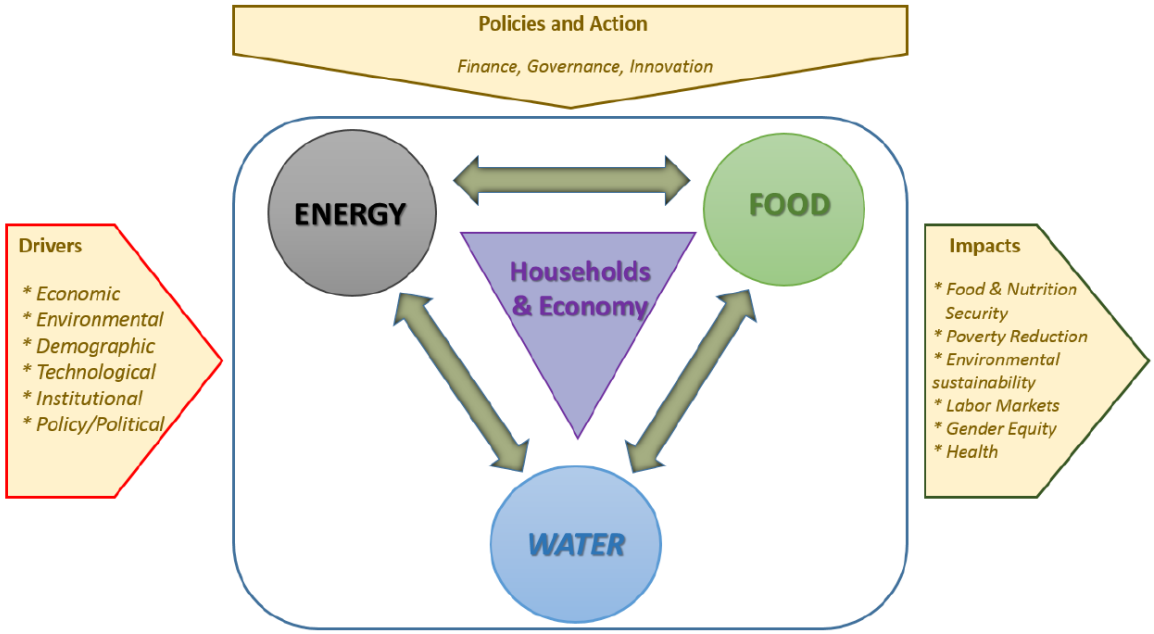


2.2.5 Develop a description of the water – energy – food Nexus

Sources of information include the following source

Hoff, H. 2011. "Understanding the Nexus." *Background Paper for the Bonn2011 Conference: The Water, Energy and Food Security Nexus*. Stockholm: Stockholm Environment Institute. http://www.water-energy-food.org/en/whats_the_nexus/background.html

Figure 1—The Water, Energy, and Food Nexus Perspective



Source: Authors' adaptation of Hoff (2011) and von Braun (2015)

2.6.1 Poor water management hurts the poor the most and the need for pro-poor policies! Write a summary of your interpretation of this statement.

Solution (from Water Resources Sustainability, Mays, 2007)

It is a well-known and documented fact that the poor and the underprivileged suffer more from lack of safe water, sanitation, and energy. Estimates for water-related mortalities range from 2.1 to 5 million a year, depending on the criteria used (Gleick, 2004). Some 2 billion people have no access to electricity at all; 1 billion people lack access to improved water supply, and 2.4 billion people lack access to improved sanitation (World Water Assessment Programme, 2003). Women and young girls spend hours everyday to fetch water and firewood in the less-developed countries of the world, thus being deprived of educational and other opportunities and suffering from the health and livelihood impacts of environmental degradation.

It then follows almost automatically that development efforts will naturally help these groups the most. After all, if the starting point is sufficiently low, any meaningful improvement would imply a higher value added for them than for those who are better off.

Empirical evidence suggests that this is not a rule. Growth alone does not necessarily mean that everybody benefits, or that all beneficiaries benefit the same. On the contrary, it has been documented that economic development may actually cause a worsening of income disparities, especially in the early phases of development. There are cases where poverty—not the income disparities—has remained unchanged in spite of sustained economic growth (Lustig and Deutsch, 1998).

The hypothesis by the 1971 Nobel Prize Winner Economist, Simon Kuznets, on the relationship between economic growth and income inequality suggested that economic growth in poor countries increased the inequalities between the rich and the poor, thus making the poor relatively worse off (Kuznets, 1955). The trend was in the opposite direction in wealthier countries. It was also suggested that higher inequalities retard growth in poorer countries and encourage growth in richer countries.

A rich, diverse literature exists as to whether this hypothesis is supported by empirical evidence worldwide and for different definitions of inequality, how it would perform if measured in income distribution terms or as applied to land tenure, and how they relate to poverty reduction, as the poor can still benefit from development even when they are worse off than the rich (Anand and Kanbur, 1993).

A conclusion from the above is the need for propoor policies in water-based development that would ensure that the poor would benefit from the public investments, basic infrastructure, increased opportunities, and the growth environment created as a result of development efforts. The levels, policy elements, and implementation modalities are to be determined on case-specific basis and by ensuring that the economic viability is still maintained at large.

It is evident that the integration of the poor and the underprivileged is an integral part of a regional development effort. When regional development is based on water resources, this becomes even more important due to the direct link between water, health, and livelihood (Unver et al., 2003).

2.6.2 Write a summary of the film World Without Water defining the central narrative and your thoughts on the film. Link to film http://topdocumentaryfilms.com/the-world-without-water/

Solution What is the central argument or narrative of the film? (Katelyn Kelly)
The central argument of this film is whether or not water should be a commodity as it has become and be privatized and traded, or if it should be a basic human right and made accessible to everyone on Earth. The film leans heavily towards making water a basic human need as it pertains almost wholly to the negative impacts of the privatization of water and the effect that it has on human populations.

2.6.3 Between 2009 and 2050, as the world population is expected to increase by 2.3 billion, urban populations are projected to grow by 2.9 billion – from 3.4 to 6.3 billion (UNDESA, 2009). Urban areas are therefore expected to absorb all of the world's population growth over the next four decades, while also drawing in some of the rural population. Furthermore, most of the urban population growth will be concentrated in the cities and towns of less developed regions which already face enormous backlogs in shelter, infrastructure and services, as well as insufficient drinking water supply, deteriorating sanitation and increasing environmental pollution. What would you say are the most important factors of water resources sustainability that must be studied to handle this urban growth, particularly in the less developed regions?

Solution A student response

As urban centers continue to grow several water resources sustainability factors must be better understood. Among these the most important ones are: (1) Resource management and allocation for a broader social and economic development (2) upstream management and (3) proper water treatment and ecosystem conservation. For the first, urban centers must understand how much water and the quality of water available is available to them, and make regulations that assures proper distribution of that water to its population. Along with that urban centers must account for industrial growth, and both allocate them proper water and regulate the quality of water that returns to the river/ source. They must not ignore the water needs of the less wealthy populations. For the second point, agreements must be made with communities up and down river that assures adequate flow of water to fit the needs of all communities. These agreements must account for extreme conditions and predict future needs/resources. The third point assures that all populations receive water that they can use despite industrial and social growth of the river. This means that the water is free of harmful substances such as heavy metals, high concentrations of agricultural waste, or fecal contamination. For this point, a proper waste water treatment plan must also be accounted for. Lastly, the distribution system must be maintained and regulated, and reuse technologies that allow for a close-cycle treatment plan can be considered.

2.6.4 The state of water resources is one of constant change, resulting from the natural variability of the Earth's climate system and the anthropogenic alteration of that system and the land surface through which the hydrological cycle is modulated. Specific changes to water resources and the hydrological cycle include:

- Changes in mean surface flows due to natural climate variability at inter-annual and multi-decadal time scales and climate change
- Modifying runoff through storage and inter-basin transfers
- Increased flood potential due to climate change
- Increased water losses due to temperature increase
- Changes in the seasonality (or timing) of flows, especially in snowmelt basins
- Changes in flows from glaciers due to their retreat
- Decreasing snow and permafrost
- Groundwater depletion – losing the buffer against rainfall variability
- Changes in soil moisture (and runoff) due to changing land surfaces for urban settlements or agriculture

To complicate the above even further global political and social systems are changing in unpredictable ways. Technology is evolving; living standards, consumption patterns and life expectancies are changing. Human populations are growing and moving to expanding urban settings. Consequently, land use and cover are changing, as is the climate. The rate of change of these events is increasing and their long-term impacts are uncertain.

In other-words we will need to learn how to manage water under uncertainty and risk which is the theme of the United Nations World Water Development Report No. 4 (WWDR4). The above two paragraphs are from the Executive Summary for the WWDR4. You can locate WWDR4 on the internet.

What's the answer for water resources sustainability? Your answer might be based upon a good look at the WWDR 4 and the other related publications with the WWDR4.

Solution The following is a student response to the above question.

I think that most people in the world wish that was an easy question to answer. There has been enormous effort to try to help create a world in which there are sustainable water resources for all, but it is an extremely large and complicated problem to solve. Water is integrally related to everything in the world and it is all interrelated. There would be no life on this blue marble in space if it was not blue – we all have water to thank for being in existence. Water resources sustainability is not an isolated problem to solve; sustainability of life on earth is dependent on it. One of the reasons there is no single answer to this question is that we live in a dynamic, ever changing world. Even if against all odds every last person on Earth had access to clean fresh water and sanitation, the world is constantly changing and the solution would have to adapt to maintain sustainability. The complications of managing water in times of geopolitical change, climate change, and other large scale changes are huge.

The United Nations World Water Development Report 4 (WWDR4), titled "Managing Water under Uncertainty and Risk" attempted to address some of these challenges. One of the principle messages of the report is that water underpins all aspects of development and that water needs to be an intrinsic element in decision-making across the whole development spectrum. In order to work toward water resources sustainability, it is critical that people understand the global importance of water and its centrality to all things. It may seem like common sense, but it is astounding how many people that I talk to in the United States have no idea where their water comes from. The idea that people in less fortunate areas have no access to clean water or sanitation, let alone have a tap running into their house, has no context. To make real progress, the importance of the issue needs to be understood. The first chapter in the WWDR4 is titled "Recognizing the centrality of water and its global dimensions", and discusses the critical nature of water.

In order to understand water resources sustainability, it is important to understand the end uses of water. Chapter 2 of the WWDR4 is titled "Water demand: What drives consumption?" Phoenix is a good example of discussing water resources sustainability without discussing the end uses. The focus seems to be always on the supply, securing more distant and hard to reach sources. The Salt and Verde rivers are completely maxed out, with 100% of their flows going into the canals feeding Phoenix. The Salt river in Tempe is nothing but a dry flood control ditch. Groundwater pumping has caused land subsidence across the valley. Huge amounts of energy and the most expensive water resources project in the history of the United States (CAP) bring Colorado river water to Phoenix. Yet there seems to be little discussion of conservation measures. There is no support or incentives for installing rainwater harvesting systems. Desert landscaping is the exception rather than the norm, and flood irrigation of thirsty green lawns is rampant. The Palo Verde nuclear energy generation plant is the largest nuclear power plant in the world not located on a large body of water. Almost all of the effluent from the Phoenix area goes to the plant, which could be used for the many golf courses that dot the valley. Discussion of

limiting some of these uses or promoting conservation has not happened, especially relative to the sheer amount of time and investment that have gone to securing supply of water from far afield.

WWDR4 states that agriculture accounts for 70% of all water withdrawn by the agricultural, municipal and industrial (including energy) sectors. Improving the efficiency of agricultural water management would make a huge difference in global water resources. Predicting demand for agricultural water is next to impossible due to the many factors that themselves have huge uncertainty. Reducing food waste and decreasing production of non-food crops could be part of the path to more water sustainable agriculture production.

Chapter 3 of WWDR4 is titled "The water resource: Variability, vulnerability and uncertainty." This deals with the risk involved on the supply side of water resources issues. In most places on Earth there is large seasonal and annual variation in precipitation and water supplies, and climate change is exacerbating the variation and uncertainty. The WWDR4 states that the global groundwater abstraction rate has at least tripled over the past 50 years. Over-withdrawal from aquifers by groundwater pumping is a huge threat to water resources sustainability. The negative effects of over-withdrawal are many. One of the biggest reasons groundwater is so important is that in many circumstances groundwater "mining" is occurring, removing water that has accumulated over many years, sometimes even thousands of years. When you drain a river, you can only take runoff from that year. Short sightedness in groundwater management now can result in water crises for future generations. Another result of this over-withdrawal is that the supply of water seems artificially high since it is bolstered by unsustainable water withdrawal. This can just kick the can down the road, and exponentially increase the severity of the issues when the groundwater does run out. There was no such thing as unsustainable groundwater withdrawals before the advent of electricity. Especially in rural areas of developing countries, traditional methods can be an amazing way to provide water in a sustainable manner.

Improving water resources sustainability has a much larger impact than less people going thirsty. Chapter 4 of the WWDR4 is titled "Beyond demand: Water's social and environmental benefits". This is related to the overall theme of the report, that water is integrally related to many crucial things that might not be traditionally associated with water resources sustainability. A good example of this is the empowerment of women. To someone not familiar with the struggle of poor women in developing countries, water resources and education may seem to be unrelated. But in actuality women are usually the ones responsible for the retrieval of water, which can take huge amounts of time and work if the closest source of water is not nearby. This water fetching time almost always has a higher immediate priority than education. The environmental effects of unsustainable water resource management are endless. Many times process such as desertification can begin due to poor water management, and can cause additional crises such as starvation. If dryland countries could reduce the impacts of desertification and drought on water resources, food security would be greatly enhanced. It's another example of how intricately related water is to food.

Chapter 6 of the WWDR4 is titled "From raw data to informed decisions". Data is an incredibly important to making decisions, as it can give the decision makers objective information about the issue they are trying to solve. We live in a time where there is more data sources than ever before. While this collection and decimation of data is crucial, it doesn't mean anything if it is not processed and used in a way to help decision makers. A good example of this is the operation of Old Hickory dam by the US Army Corps of Engineers. Even in the presence of sufficient real time data, the dam operators used antiquated techniques for dam releases during a flood, causing extensive damage. Daniel Che showed that had the data been used in real time to make the release decisions, the flood stage would most likely have been kept below the 100 year flood stage. Even in an advanced country like the United States, the data available is not being used to make critical decisions. More effective use of data available would improve water resources sustainability.

Incorporating sustainable thinking into water management is important to ensure water resources sustainability goals are moving forward. There have been many frameworks and other management schemes proposed, one of which that has gained popularity is integrated water resources management. Integrated water resources management (IWRM) is a framework based on the Dublin principles designed to aid in a more holistic view of water management. One of the key concepts presented as part of the IWRM framework is that water management should be applied at the watershed level. This allows for all of the players in a catchment or watershed to be involved in the management of its water resources, and the consequences of water resource management decisions are internalized.

Water management and environmental management are intricately linked, and the integration of the two is a central principle of IWRM. The health of ecosystems is entirely dependent on water, and the two should be managed together because of the direct interdependence. A systems approach should be used for the management of water, at the watershed scale. Management of water resources with a systems approach at the watershed scale will put decisions in context. Full participation by all stakeholders, including workers and the community, is a central idea to IWRM. By engaging with all of the stakeholders in a watershed, ideally the concerns of all of the stakeholders will be taken into account. This is hard in large watersheds, and an important reason to incorporate a systems approach at the watershed level. When watersheds are subdivided into different management areas, it is unlikely all of the stakeholders will participate as the structure is not set up for a holistic view.

Water resources sustainability is a goal that is incredibly complex to achieve. There are many facets of water resources that need to be addressed, and so many water challenges are unique to local circumstances. The changing, dynamic nature of our world and the interconnectedness of water to everything else can be daunting and incredibly hard to plan for. We owe to ourselves, the rest of the planet, and future generations to do the best we can to work towards water resources sustainability. I believe the answer to water resources sustainability lies in the ingenuity and resilience of human beings.

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