Flat, Dry and Salty:

Understanding Australia's Salinity

Introduction

Australia's salinity levels have been a major focus of domestic water management policies for decades. Understanding how and where salinity comes from is complex. It requires an understanding of the Australian continent and how its unique geography and arid climate drives salt accumulation as well as how human practices and management interact with natural systems. For the UN 2020 Data Drive, Australia reported on salinity at the national level, focusing on a reporting period of 1 January 2017 to 31 December 2019. This is the first SDG Indicator 6.3.2 Data Drive Australia has participated in. The results reveal that Australia generally had satisfactory salinity levels during the reporting period. The analysis also highlights the variability of water quality in Australia and the complexity of defining natural conditions.

Background

Australian has a complex and variable climate. Rainfall and weather systems can change dramatically due to climate drivers such as the El Niño-Southern Oscillation (ENSO) (Bureau of Meteorology, CSIRO 2016). Australia's unique climate creates some of the most variable rainfall in the world and contributes to river systems with mean annual discharges more than a 1000 times more variable than most European and North American rivers (Dey, et al., 2019; Pain, et al., 2012). The Australian continent is also extremely flat, with an estimated average slope of only 1.4^{o} and low, with an average elevation of around 325m and a maximum elevation not exceeding 2,230m aSL (Pain, et al. 2012). Salt can be introduced to river systems through rock weathering and wind and rain deposition (Water Quality Australia n.d.). Australia's low rainfall and gradient creates slow flowing river systems that drain internally and often evaporate leaving salts behind instead of draining them to sea (Pain, et al. 2012). Almost half of the Australian continent provides no runoff to surrounding oceans, in stark contrast to all other inhabited continents (Pain, et al. 2012). These unique climatic and geographic factors create a system that favours salt accumulation.

While salt accumulation is natural in Australia, a range of human practices can exacerbate secondary salinisation. For example, dryland salinity occurs when deep-rooted native plants are removed or replaced with shallow-rooted plants

Ord River Floodplain (Copyright Department of Agriculture, Water & the Environment (Taken by staff)) (e.g. crops) that use less water, causing a rise in the water table (Water Quality Australia n.d.). Rising water tables mobilise salts from the soil and deposit them on the surface. Interestingly, drought conditions have caused dryland salinity to decrease by lowering the water table in some areas. Salinisation can also occur when excess irrigation water is applied to crops, causing water tables to rise and increase surface salinity. In groundwater, increased salinity can occur due to rising water tables and subsequent direct evapotranspiration which increases groundwater salt concentration. Salinisation can also occur due to pumping which can cause stratified groundwater to mix and contaminate fresher layers and at times, due to poorly constructed wells (Greene, et al. 2016). In coastal aquifers, overuse can drive increased salinity via seawater intrusion into fresher groundwater systems (Greene, et al. 2016).

Secondary salinity issues emerged in Australia in the late 1960s and by the mid-1980s 96,000 hectares of irrigated land in the Murray-Darling Basin (the Basin) were showing visible signs of salinisation (Murray-Darling Basin Authority, 2015). This caused policy makers to enact strategies to manage water and soil salinity (Hart, et al. 2020). Action on salinity included improving crop drainage, salt interception schemes, salinity caps and clear salinity frameworks and targets (Murray-Darling Basin Authority 2015). These management strategies had significant success and helped avoid serious environmental and economic consequences in the Basin (Murray-Darling Basin Authority 2015). While salinity has reduced in recent decades, careful management is needed to ensure salinity does not return to previous levels (Murray-Darling Basin Authority 2015).

Information is an important tool in water quality management. While national-scale water information has expanded dramatically, there is no single comprehensive national repository of water quality data in Australia. Water resource sharing and wastewater management is primarily a state and territory government responsibility. As such, state and territories manage a range of water quality monitoring programs and associated databases for a variety of purposes. The Bureau of Meteorology (BOM) plays an important role for consolidating water information nationally but does not yet have consolidated data for all SDG6.3.2 parameters.

Australia's SDG6.3.2 Method

Surface water method

For surface water, river gauges in BOM's data archive were used for analysis if they were in ongoing operation and had 18 years of continuous data (to allow for statistical analysis). While 900 gauges across Australia had salinity data, only 374 gauges met these requirements. Salinity measurements were pre-processed to remove spurious data, e.g. negative or zero values, respectively implausible data (<15 µS/cm and >100,000 µS/cm). The observations were split into a reference period (Jan 2001 to Dec 2016) and a reporting period (Jan 2017- Dec 2019). A reference period of 15 years was applied to maximise historical data used while maintaining appropriate spatial representation of available sites with high-quality datasets. Surface water targets were calculated based on the 5th and 95th reference period percentiles. The 5th and 95th percentiles were selected as targets due to their use in the UNEP worked Chilean example and Australia's comparative natural variability. The UNEP's compliance proportion of 80% was applied to the reporting period to classify gauges as 'good' or not (i.e. 80% or more of reporting period observations lie within the target range).

Groundwater method

Similarly, for groundwater, bore salinity data were accessed via BOM's National Groundwater Information System (NGIS) salinity database. Over a million salinity observations at approximately 200,000 bore locations where retrieved from the database. Observations were pre-processed to remove duplicates and standardise units. Bore observations were split between a reference period (Jan 1967–Dec 2016) and a reporting period (Jan 2017- Dec 2019). A bore was deemed to be suitable for analysis if it had 10 observations in the reference period. This minimum data requirement was necessary due to the general scarcity of groundwater salinity observations. After applying the minimum data requirement, 2,492 bores remained for analysis. A groundwater target was calculated for each bore based on the 95th percentile of reference period observations. No lower boundary was applied as low groundwater salinity (i.e. below the 5th percentile) would rarely be considered as 'poor quality' in Australia. The UNEP's compliance proportion of 80% was applied to the reporting period to classify bores as 'good' or not.

Division of water body types

For the 2020 Data Drive, Australia did not separate surface water into rivers and lakes. In Australia, the key water monitoring division is between surface and groundwater. The Australian landscape substantially differs to much of the Northern Hemisphere as a result of a long history of erosion from wind and water, which left a flat, low landscape. This geography, when combined with Australia's arid climate, leads to nearly half of Australia consisting of areas that either drain internally or lack recognisable river systems (Pain, et al. 2012). Most Australian rivers show a consistent loss of flood discharge downstream with some ending in flood-outs or in closed (often salt laden) lake systems (Pain, et al. 2012). Many of these lakes are ephemeral and rarely have water in them. As such, monitoring is focused on where water is used which is primarily in rivers, not lakes.

Water body definition

SDG6.3.2 is measured in terms of 'water bodies'. The UNEP defines water bodies as 'a section or tributary of a river, a lake or an aquifer', ideally with homogenous water quality. Australia divides its water systems differently depending on the purpose of the analysis. Options for division include river regions, drainage basins or the National Groundwater Information System aquifer boundaries. In water quality analysis care must be taken to ensure aggregations are representative, given that flow and salinity dynamics at individual sites can be complex. Build-up of salinity sources, the frequency and nature of flushing events, fluctuations in river flow, groundwater–surface water interactions and groundwater salinity can all impact an individual site's water quality (BOM 2018). Australia wanted to ensure that any water body aggregation used was representative. Due to lack of resources, comprehensive analysis on how best define representative water bodies for SDG6.3.2 was not possible and therefore, each monitoring station was defined as its own water body. Future Australian data submissions may choose to revise this methodology choice.

Discussion

Effect of the reference period and reporting period start and end dates

Using this method, water quality at monitoring stations are defined relative to the reference period's normal ranges. As such, the dates chosen for reference periods play an important role in determining the results. Ideally, target values would be determined using natural conditions before colonisation. Widespread land clearing, water extraction and river regulation has occurred in Australia since European settlement in the early 1800s which has likely increased salinity levels (Hart, et al., 2020; Argent, 2017; Murray-Darling Basin Authority, 2015). However, high-quality salinity time series data prior to 2000 is scarce and thus targets cannot be defined before then.

Surface water's 15-year reference period included two of the most extreme weather events Australia has on record: the Millennium drought (1996-2010) and record high rainfall during the previous La Niña period (2010-2011) (Bureau of Meteorology 2015). Further, rainfalls during the reporting period (2017-2019) were the lowest on record for much of eastern Australia, breaking records originally set during the Federation Drought (1900-1902) (Bureau of Meteorology 2020). These events will have had an impact on the SDG6.3.2 targets and results. Further, while it is possible that climate change will increase extreme events its exact influence on the reference period is difficult to calculate. Future data drives will need to consider options of testing the representativeness of surface water's 15-year reference period.

Comparatively, groundwater analysis used a 50-year reference period (Jan 1967–Dec 2016) and a minimum data requirement of only 10 observations. Few bores have time series data for salinity. Regularly, bores with adequate water quality are only measured a few times to confirm their usability. Frequent salinity measurements tend only to be taken at bores with known water quality issues, therefore increasing the minimum data requirement may bias results towards poor quality sites.

Circumstances where groundwater requires a lower boundary

For the 2020 Data Drive, only an upper, 95th percentile target was applied to bores as few groundwater managers consider freshening aquifers to be a water quality issue. While this is mostly true, there may be some exceptions. Aquatic environments have adapted to a range of salt concentrations in Australia (Bureau of Meteorology 2016). If naturally saline aquifers become too fresh, saline-based ecosystems could potentially be degraded. In addition, occasionally a freshening groundwater system can indicate that a nearby river has changed from a gaining stream to a losing stream (Badenhop and Timms 2012). This can occur due to increased groundwater extraction, leading aquifers to leach fresher water from rivers (Greene, et al. 2016). The extent and impacts of this phenomenon are not currently known (Greene, et al. 2016). Future data drives may want to investigate these cases further to confirm applying a lower boundary is inappropriate for groundwater.

Future avenues to reporting on other parameters

Future submissions may choose to work closer with state and territory governments and other science agencies, such as CSIRO, to source more data. Other SDG6.3.2 parameters may not require individual targets for each site and therefore might have less intensive minimum data requirements. Level 2 reporting also provides the opportunity to submit water quality monitoring data not captured by the Level 1 parameters. Australia may consider submitting turbidity, bacteria and algae, nutrients, or total suspended sediments (TDS). Remote sensing data may play an increased role in Australian SDG6.3.2 submissions through projects such as AquaWatch. Remote sensing can provide insight on water quality and could provide wider coverage of the Australian continent.

Conclusions

Reporting on SDG6.3.2 is a useful process that provides a greater understanding of variability and extremes in Australian salinity. Calculating the change in a site's water quality can reveal long term trends and highlight issues. However, equally important is understanding why water quality might be changing. Separating out the effects of policies, practices, climate and other salinity influences is important to understand how to effectively manage problem sites. This information cannot be elucidated from SDG6.3.2 alone so further analysis must be done for effective water quality management.

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