FINAL REPORT

CSA00042

Web based visualization of spatial and temporal yield gap information for grain growers and strategic research investment planning

PROJECT DETAILS

PROJECT CODE:	CSA00042
PROJECT TITLE:	WEB BASED VISUALIZATION OF SPATIAL AND TEMPORAL YIELD GAP INFORMATION FOR GRAIN GROWERS AND STRATEGIC RESEARCH INVESTMENT PLANNING
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Summary

This project developed the Yield Gap Australia Website (www.yieldgapaustralia.com.au). The site provides an interactive map-based tool for grain growers, agronomists, research funders and policy makers. It shows the extent and geographic distribution of the gap, between yields currently achieved on farms and those that can be achieved, by using the best adapted crop varieties and best crop and land management practices as key ways to increase productivity. It provides a visual and quantitative description of the magnitude of the yield gaps, where they are distributed and how they vary under different seasonal conditions.

Conclusions

This project developed a website that provides an interactive map-based tool for visualising the extent and geographic distribution of the yield gap, between actual and potential production of rain-fed wheat crops in Australia. The functionality proposed at the outset of the project has been achieved and there is potential to build on this platform, for example by adding more crops. A system to capture user feedback has been designed and implemented, so that it can guide further improvements and new functionality can be developed in response to user demand. The website has the potential to serve as a platform for further research on the causes of yield gaps (e.g. subsoil constraints, soil borne diseases, socio-economic factors, etc.).

It has the potential to serve as a benchmark for monitoring future productivity improvements and many further applications, which explore the potential impacts of both positive and negative factors on the whole of the grains industry. It is too early to estimate the impact of this tool, given the short time it has been available and limited exposure to a select audience. However, it has already led to lively and important discussions about the gap, and between actual and water limited yields in Australia's wheat crop. Further time and development in response to user feedback is required to ensure that the potential impacts of this project are realised.

Recommendations

Based on the experience of developing the website, an appreciation of the potential of the site to serve as a benchmark and platform for future productivity research, and the feedback received to date, it is recommended the GRDC and CSIRO continue to support the maintenance and user-oriented development of the Yield Gap Australia website.
Important activities that require support are:
1. Promote the http://yieldgapaustralia.com.au site to potential users.
2. Improve the performance and functionality of the site in response to user feedback.
3. Update the site to cover water limited yields (Yw) and actual wheat yields (Ya) from 2011 to 2014.
4. Provide a platform for adding more crops (canola, sorghum, etc).
5. Investigate causes of yield gaps.
6. Benchmark water productivity.
7. Provide support to other GRDC funded projects (e.g. costs of edaphic stress to the Australian grains industry).

Outcomes

Information about yield gaps is valuable for two types of stakeholders:

1. Those who direct investment in agricultural research and development (R&D), and

2. Grain growers and their agronomic advisers, who can use this information to benchmark their own performances or the performance of their clients.

The main purpose of this project was to provide tools that enable both stakeholder groups to access and use the yield gap maps developed in the CSIRO's Agriculture Flagship project 'Yield Gap Analysis and Diagnosis'.
These data can serve as a benchmark for evaluating progress in yields and water productivity in future years. Wide-spread visual access to these data should stimulate further enquiry about why some statistical local areas (SLAs) have larger yield gaps than others, and about what are the important causes of these yield gaps.

Achievements/Benefits

Users of this website can select between maps that show actual yields derived from the Australian Bureau of Statistics (ABS) data; Water limited yields (Yw) calculated from the Agricultural Production Systems sIMulator (APSIM) simulations using daily weather and soil data; the yield gap (Yg) which is the difference between Yw and Ya; and relative yields (Y%) which is Ya expressed as a percentage of Yw.

Users can explore these maps at a range of scales: at 297 SLAs, 14 Agro Ecological Zones (AEZs) and three GRDC-Region levels of resolution. They can also choose to look at 15 year average values or at individual years (1996-2010).

In addition to visual displays, they can obtain detailed data on their area of interest, by clicking on the relevant area of the map. Growers and their advisers can use a 'Compare My Farm' tool to benchmark their farms against, both the local average yields and the local water limited yield potential, adjusted for their farm's soil types.

The Yield Gap Australia website is making maps of the best estimates of Australia's wheat yield gaps available to the public, with the expectation that they will be used to:
1. Benchmark individual farm yields, against their water limited potential and the local average yields on the same soil type.
2. Prioritise research and inform agricultural policies to ensure global food security, through focus on regions with the largest unexploited yield gaps and greatest potential to close them through ecological intensification.
3. Help researchers to identify the causes of yield gaps and locations, where new technologies or technology packages have greatest potential.

Methodology
The yield gap calculations displayed on this website are based on 15 years of data (1996 to 2010). This period is long enough to account for climate variability, but short enough not to be substantially affected by technology change and climate change.

Actual yields (Ya): The ABS collates national agricultural production data at the level of statistical local area (SLA; roughly equivalent to local shires or district councils) every five years when the national census is carried out, and at the coarser scale of statistical division (SD; which comprise of a number of SLAs) annually.

For those years, where only SD level data were available, SLA crop yields (t/ha) were calculated from SD data by using linear regressions fitted to SLA level data from 17 past census years.

Water limited potential yields (Yw):

Water limited potential yields (potential yields) are best determined with a locally validated crop simulation model (van Ittersum et al. 2013). The APSIM is a well validated cropping system model that is widely used in Australia, as well as many other countries (Keating et al. 2003, Holzworth et al. 2014). It was therefore used here to generate water limited potential yield estimates for the entire Australian wheat growing area. APSIM combines weather data, soil data, crop varieties and crop management rules to simulate crop production.

Water limited potential yields were estimated for almost 4,000 weather stations and then interpolated across the Australian cereal cropping zone to generate estimates for each SLA. The APSIM simulations were carried out assuming current best practice and unlimited crop nutrition, to ensure that water (made up of rainfall plus stored soil moisture at sowing) and climate were the only factors limiting crop growth.

Weather data was sourced from SILO Long Paddock (using the Patched Point dataset) in which, recorded daily station data are augmented with interpolated data in order to generate complete daily datasets of solar radiation, temperature, rainfall, evaporation and vapour pressure for the several thousand stations in the cereal cropping zone. Simulations were run for each weather station and it was assumed that the results applied to a 20km radius around each weather station. Given the relatively simple landscape of much of the wheat growing areas of Australia, this is a conservative estimate.

The nine major soil types used for growing wheat in Australia were identified from the Australian Soil Resources Information System (ASRIS) maps. Their average water holding capacities were derived from the APSoil database. Separate simulations were run for up to three of the most common soil types, which occur within the area bound by the 20km radius of each weather station. Yield results were then aggregated, weighted by wheat land use area of each soil type, to calculate a single estimate of Yw for each weather station.

Five wheat maturity types were simulated for each weather station and soil combination. The maturity type, which gave the highest average yield over the fifteen year period, was chosen for use in the calculation of Yw for that station. The maturity types were: early maturing (e.g. Mace(|)); mid-early maturing (e.g. Scout(|)); mid maturing e.g. Derrimut(|)); mid-late maturing (e.g. Endure(|)); and late maturing (e.g. Bolac(|)).
APSIM simulations include management rules for sowing dates and fertiliser application. Sowing dates were based on latitude (i.e. north or south of Dubbo at latitude -32.243815), rainfall and soil plant available water (PAW).

For northern locations:
Sow if rain >= 15mm over three days and PAW >= 30mm from April 26-July 15.

For southern sites:
Sow if rain >=15mm over three days regardless of soil moisture from April 26-July 15.
If the above criteria were not met, the simulated crop was dry-sown on July 15. Sowing density was 150 plants per metre, row spacing was 0.25m and sowing depth was 3cm.

To ensure that rainfall was the only factor limiting crop growth in the simulations, nutrients (i.e. soil nitrate) were topped up by 50kg nitrogen (N)/ha, whenever soil nitrate in the top 60cm was less than 50kgN/ha up to anthesis.

Yw yields were aggregated for each met station, by weighting the soil type simulations, by their wheat land use areas. Local kriging was used to smooth out the individual met station estimates, to determine annual Yw values for each SLA and each year.

The yield gap (Yg) and relative yield (Y%) were calculated from the actual yield (Ya) and water limited yield (Yw) for each SLA and year.
Yg = Yw - Ya
Y% = 100 x Ya / Yw

Soil specific Yw yields (used in Compare My Farm tool):

An estimate of potential yield for each Australian Soil Classification (ASC) soil type within each SLA was produced for the Compare My Farm tool. The water limited potential yields, calculated for the different soil types at each weather station, were averaged within each SLA. This produced Yw estimates for between one and seven soil types in each SLA. To enable users to reliably identify the ASC soil types on their farms, soil names are linked to simple description based on Isbell (1996) and the CSIRO/ACLEP/ASC Soil Poster, which also contains photographic depictions of theses soils. A link to the poster (http://www.clw.csiro.au/aclep/asc/Soil_Poster.pdf) is provided.

Web Design
The data and maps were developed as part of a separate strategic CSIRO project. The focus of this project was to make these maps available to the public in an accessible and interactive form. Following discussions with GRDC managers, CSIRO colleagues and a number of growers and agronomists, other map based websites and apps such as the GYGA site (http://www.yieldgap.org/web/guest/home) SoilMapp (https://wiki.csiro.au/display/soilmappdoc/SoilMapp+Home) were investigated along with and other sites (www.evergraze.com.au ; http://nrmveg.mappingsa.com.au/ ; http://www.diabetesqld.org.au/about-diabetes/diabetes-information/diabetes-epidemic/diabetes-prevalence/all-diabetes/map.aspx) to develop ideas about the basic design and functionality of the site.

These ideas were captured in a PowerPoint presentation, which was a mock-up of the key functionality of the website. The PowerPoint mock-up was presented to two reference groups (one of growers and advisers in Victoria (VIC) and one to agronomic advisers in South Australia (SA)). These meetings were audio recorded and feedback was carefully considered in revising the design of the website. A more complete specification of the site design requirements was drawn up and sent to nine prospective developers for their competitive bids. Six bids were received and Mapping Services Australia was selected and contracted to develop the site.

Prior to completion, the site was demonstrated to a number of GRDC managers for feedback, before it was published online on February 9, 2015. On that date, GRDC panel members were invited to inspect the site and provide their feedback, both as users and based on their intimate knowledge of different parts of the grain zone. This feedback has been captured in a spreadsheet, which will be maintained as a record of feedback and actions taken. This feedback has revealed a number of issues that are currently being addressed before the site is officially launched and promoted.

Issues to be resolved
GRDC panel members have correctly identified that Yw is under-estimated for some SLAs such as Junee. The cause of this error, which affects about 30% of SLAs to varying (mostly minor) degrees has been identified. Yw for all SLAs are currently being recalculated and the problem is expected to be corrected by March 6.

Both GRDC managers and panel members have identified that some SLAs with high Y% (small yield gaps) have a significant amount of wheat grown under irrigation. The consequence of this is that their Ya value is boosted by the higher yields obtained under irrigation. This issue affects 15 of 297 SLAs. Unfortunately, the data required to 'correct' this value so that only rain-fed yields are included in the Ya estimate is not available.

It is proposed instead to use icons to alert users that the results for these SLAs are influenced by irrigated wheat. The SLAs affected have been identified and it is expected the solution to this issue will be implemented by March 6.

GRDC panel members from the Northern Region questioned the lower than expected average Yw values for the Liverpool Plains and Eastern Downs. This query points to a communication issue, rather than a technical one. The yield gap analysis is based on a mean cropping system for the region. It does not account for the many and varied crop rotations that exist in the northern region, but rather relies on the average cropping intensity in the region, which is very close to one crop per year, even though this is achieved by various combinations of short and long fallows, with the odd double cropping situation.

Yw is calculated on the assumption of a short fallow (wheat following a winter crop). While this is justified on average, growers who grow wheat on long fallows will experience higher yields. This does not mean that they are achieving Yw, because the Yw for such crops is higher than the one calculated in this analysis, as more water has accumulated in the soil during the long fallows. Yw can be calculated for wheat crops following a long fallow. This would show that Yw calculations can account for the high yields achieved by growers practising this fallow and would be useful in the 'Compare my Farm' tool, but it should not be used for calculating the average yield gap. This issue is best solved through communication with Northern Panel members and leading agronomists and growers in the region.

Adviser feedback emphasised the importance of keeping the website up to date. This suggests that the yield gap be updated on an annual basis, so that these annual updates can be included in pre-season planning discussions between advisers and their clients.

Other research

Evaluation of Climate-Smart agriculture (CSA) options for adapting crop production and building resilience to climate change, and reducing greenhouse gas (GHG) emissions.
There are many paths to achieve CSA goals, including all aspects of crop, soil, and water management, from tactical considerations involving time of sowing and crop maturity, to nutrient, water, and pest management, as well as strategic decisions about crop selection, rotations, and multiple cropping.

While field studies can evaluate and identify a set of 'climate smart' practices that function well at a given location in today's climate, it is not possible to evaluate them in future climates. Cropping system simulation provides a means to perform such ex-ante evaluations in future climates.

Past CSA studies have selected a limited number of weather stations to perform these studies and have assumed that the results are representative of the whole grain zone. It has been asked if there is value to using a 'bottom-up' approach that upscales observed weather data from a network of weather stations located throughout the crop production area, to provide a robust estimate of crop production capacity under climate change at local to regional scales. A bottom-up approach would impose a climate change scenario on long-term daily weather data from existing stations and then upscale through SLAs, agro-ecological zones (AEZs) and regions to a national scale. Initially, only the effect of temperature and atmospheric [CO_2] would be evaluated, because model projections of rainfall change vary much more, than projections of temperature change. At issue, then, is how to perform the upscaling.

The upscaling protocol used to estimate wheat yield gaps in Australia provides a robust estimate of rainfed (Yw) yield potential using close to 4,000 weather stations. Data on soil properties and crop management employed by growers in proximity to each weather station, represented by a 20km buffer zone, are used as input to APSIM. Simulated yields are then aggregated within spatial units, based on weighting each weather station on the basis of its wheat crop production area.

A bottom-up approach is proposed for assessing impact of climate change and CSA options on crop production capacity, via the following approach:

1. Identify the minimum number of weather stations and associated buffer zones within climate zones to achieve acceptable accuracy of Yw at the spatial scale of interest (e.g. SLA, AEZ or regions). This will provide a tractable number of locations where detailed data are required to support simulation.
2. Impose a climate change scenario weather database for a target year (e.g. 2050) on the daily weather data for each weather station, by increasing the daily maximum and minimum temperature, by the average increase in temperature and atmospheric [CO_2] predicted for that location, by an ensemble of global climate change models (GCMs).
3. Using APSIM, simulate Yw obtained by CSA options under the climate change scenario weather database, across the major soil types used for crop production using optimisation procedures to identify the crop calendars that optimise yields with acceptable levels of risk (i.e. coefficient of variation in yield).
4. Upscale estimates of crop production potential under different CSA options, by weighting estimates of crop production within each buffer zone, by proportion of total crop area within the spatial unit of aggregation.

Intellectual property summary

A copyright notice is included in the website. There are no plans to commercialise any outputs of this project.

Additional information

The key publication produced by this project is the website http://www.yieldgapaustralia.com.au/

Zvi Hochman, David Gobbett, Heidi Horan, Di Prestwidge Javier Navarro Garcia. 2014. Benchmarking wheat yield gaps in water-limited production environments of Australia. Proceedings of Water for Food Conference, Seattle, USA. Oct 2014.