Virtual farming systems to communicate climate change impact data to farming communities

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Abstract: *This paper describes a project developed to help communicate and provide access to data relative to climate change impact on farming systems. We developed a number of web enabled visualization products for illustrating present and potential future farming systems and help improve the communicability of climate change related information to local farming communities and other stakeholders. Our prototype virtual farming system focused on a dairy farm in South West Victoria, Australia. The produced visualizations and information were brought together in the Google Earth digital globe environment and made available online to stakeholders. The use of a digital globe interface allowed the creation of a contextualized virtual farming system that could be explored by the user and where hyperlinks could be activated to obtain detailed information on climate change impacts model outputs for that particular farm. A stakeholder workshop was then conducted to evaluate the capacity of each visualization help communicate climate change data, and early findings are presented.*

Keywords: *Climate change visualization, Google Earth, 3D visualization, data visualization, data communication*

Introduction

Climate change is likely to be one of the largest environmental challenges of our time and has the potential to affect the way of life and practices of a large number of people across the world. The agriculture industry, which success or failure can often be directly influenced by climatic conditions, such as temperature, rainfall or extreme weather events is therefore likely to be strongly affected by the projected climate changes. The potential impacts of climate change on agriculture have received a lot of attention since the fist IPCC report in 1991 and our understanding of climate has been progressing steadily. More and more climate projections are now becoming available and are increasingly being used, in combination with agricultural crop models to forecast where and how production could be affected in the future.

It is therefore very important that information allowing forward planning and adaptation be provided to stakeholders in the farming industry to enable them to adapt their practices to benefit from new arising opportunities or alleviate potential negative impacts.

While much attention has been given to the climate science and predictive modelling, much less work has been done in the area of climate change and impacts communication and stakeholder engagement. The issue of communication is particularly important because climate change, like most complex problems for which consequences and impacts are long term and relatively abstract, are particularly difficult to communicate. Traditional means of data communication such as written report, paper maps, tables and fact-sheets are limited in their potential to communicate temporal changes and spatial variations. Their use also limits the capacity to display and communicate the uncertainty and variability associated with the emission scenarios underlying climate change projections. Stakeholders may therefore find it difficult to relate to data presented through traditional data communication mediums and the apparent irrelevance of the presented data in their eye may often lead to scepticism and rejection of the presented information.

This paper describes work developed as part of the Australian Victorian Climate Change Adaptation program (VCCAP), a research project that generates and collects large amount of scientific information relative to climate change projections, impact and potential adaptation across a wide range of disciplines. Its aim is to increase the knowledge and capabilities of stakeholders ranging from policy makers to farming businesses to prepare and adapt to climate change and minimize associated socio-economical and environmental risks. To assist with the delivery and communication of VCCAP research findings to local farming communities and other stakeholders, we investigated the use of new computer technologies such as Web pages, video animations and digital globes.

Our goal was to test if these new technologies could provide tools to help better communicate and engage with farmers and decision makers in regards to climate change implications for their industry; as well as provide a medium through which projection and impact data could effectively be transferred from the scientists to the end users on the ground.

Methods and approaches

The development of our data visualization products aimed at satisfying the below described criterions, which we believe are essential to effective data communication.

1. *Relevance*: we focused on presenting data that was relevant or meaningful from the perspective of the targeted stakeholders, in terms of the variables being presented, their spatial scale and the time period over which they were considered.
2. *Spatial contextualization*: we wanted to present data in a spatial context relative to the stakeholders so they could easily be able to place or envision the data in a familiar spatial context (i.e. the extent of their farm or places they are familiar with).
3. *Ease of access*: we wanted our data visualization products to be easily found online and accessed by stakeholders so they could review it at any time and place of their convenience.
4. *Easy to understand:* we presented scientific data in multiple formats ranging from raw tabular data to photo realistic illustrations so as to be understandable to a wide audience.

To test the capacity of new computer visualization technologies to improve the communicability of climate change projection and modelled impacts to local stakeholders, we developed a set of data visualization products that focused on a specific dairy farm “Demo Dairy”, located in South West Victoria, Australia. The developed products made use of a combination of four technologies, (i) digital globe, (ii) 3D realistic images and panoramas, (iii) online videos, and (iv) web pages, which were brought together to create a virtual Demo Dairy environment.

(i) Digital Globes

The digital globe technology, around which most of our visualization products were designed, was selected because it provides free and easy access to functionalities previously only available in Geographical Information Systems, such as the display of spatial features (maps) in a geo-referenced context. Providing access to contextualizing high quality satellite and aerial imagery as well as terrain data and allowing user to zoom in and out of location with progressive accuracy, this technology represents a unique platform though which local and large scale spatial data can be presented (for more details on digital globes features, see Aurambout et al., (2008)).

Digital Globes have sparked enormous public interest over the last 5 years and are now commonly found on everyday desktop computers. We therefore assumed that our stakeholders would be familiar with this technology and would not require installing additional software to view our visualization products. Out of the plethora of digital globes currently freely available online, we chose Google Earth Keyhole Markup Language (KML) as our developing platform, based on previous investigative work on digital globes and their specific functionalities and potential (Aurambout and Pettit, 2008; Aurambout et al., 2008).

We developed two visualization products making use of Google Earth functionalities.

The first product was designed as a climate change projection and impact data exploratory interface at the local scale. It made use of several KML Placemarks (clickable points) placed on the Demo Dairy property (see Figure 1a and 1b). Each Placemark was associated with an html window (referred here as a “balloon”) that allowed to link text or image to each point. Traditional KML balloons only associate one page to each Placemark. To overcome this limitation, we made use of Adobe Flash technology to create multiple “tabs” (Figure 2a, b, c), allowing user to “browse” through multiple datasets for a same Placemark.

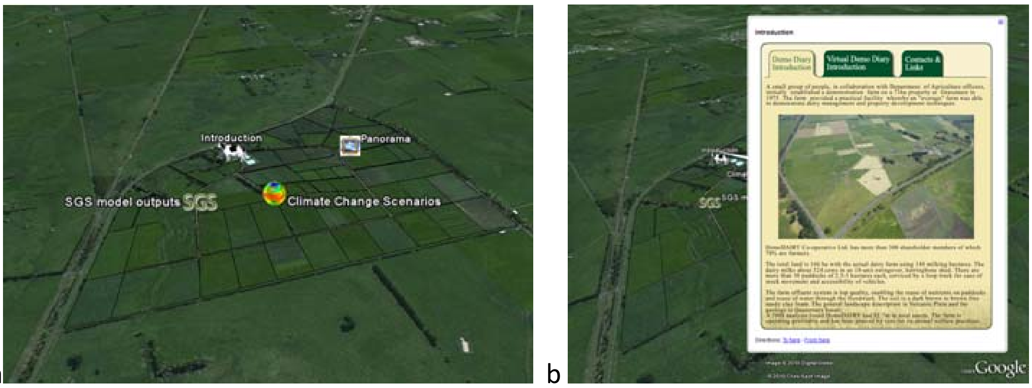
a  b

Figure 1. screenshot of the Google Earth data exploration interface. (a) Screenshot of Placemarks appearing as clickable icons. (b) Interface displaying the associated balloon appearing on click of each Placemark.

Information relative to climate records (obtained from the Australian bureau of meteorology) and climate change projection (obtained from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Ozclim climate generator (http://www.csiro.au/ozclim)) for the Demo Dairy site was brought together in a balloon associated to one of the site’s Placemark. This balloon was composed of thee tabs: The first one (Figure 2a) presented data on annual average temperature and cumulative rainfall for the 1961-1990 period and projected 2070 year (under an A1FI emission scenario) in a table format. The second tab provided access to detailed graphs of maximum, minimum temperature and rainfall comparing the years 1961-1990, 1998-07 (an unusually dry period in Victoria), 2020 and 2050 on a monthly basis. These time periods were chosen to relate more easily with farmer’s planning time frames than the typical year 2100 considered in climate change projections. The third tab was linked to official website and scientific papers relative to climate change science or modelling in an effort to allow user to get access to raw data or learn more about climate projections.

Information relative to projections of future pasture growth at the Demo Dairy site (obtained from an application of the sustainable grazing system (SGS) pasture growth model (Cullen et al., 2008) were provided in another Placemark (Figure 2c). Its associated balloon provided a graphical and tabular comparison between pasture growth rate and yield between 2000 and 2070 for low, medium and high emissions scenarios. This balloon was also developed using tabs that provided a short description of the SGS models as well as links to more detail reports explaining the structure and functioning of this model.

Although the interface presented above was designed for the Demo Dairy specific location, this approach can easily automated and extended to cover a large number of data points (such as all local weather stations in a country, or the centroid points of gridded surfaces).

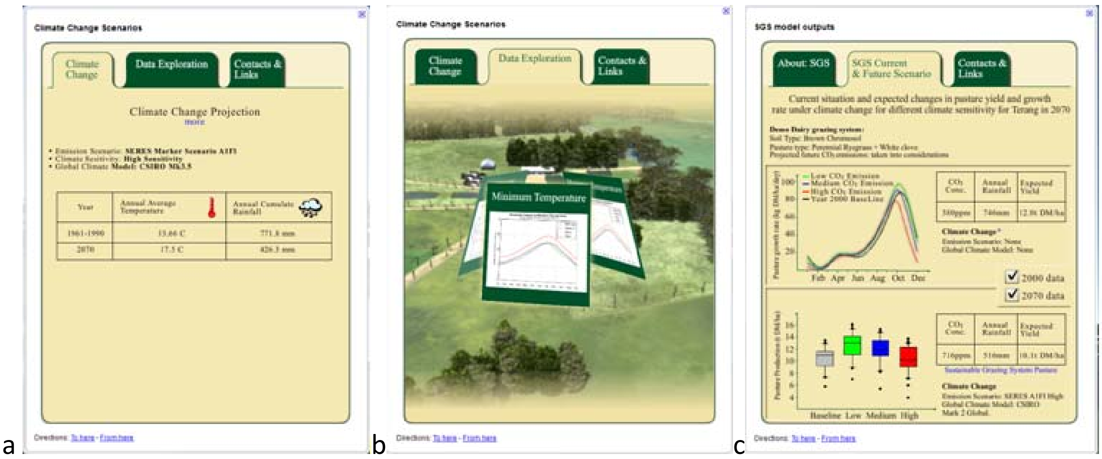


Figure 2. Overview of the Demo Dairy data exploration portal (a) Illistration of current and projected annual temperature and rainfall, (b) graphs of monthly temperature variations for maximun, minimum temperature and rainfall varialbes and (c) projections current and future of pasture growth.

The second data visualization product making direct use of digital globe technology was entitled “the moving farm” and was designed to help farmers relate to climate change and understand its implications using locations and climates they are familiar with rather than abstract climate parameters. It aimed at answering the following questions: (1) “if the farm could be moved within Victoria, where should it be placed in the future to receive an identical average temperature and rainfall regime than Demo Dairy presently experiences?” and (2) “where should the farm be moved today to experience climate conditions Demo Dairy may be exposed to in 2070?”

We used a simple GIS analysis (conducted using ESRI ArcGIS 9.3) to answer the above questions. We first related Demo Dairy’s current locations with gridded surfaces of annual temperature and cumulative rainfall records (obtained from the Bureau of meteorology), to identify the farm “climatic envelope”. We then used gridded surfaces of temperature and rainfall for 2070 (A1FI emission scenario) to identify locations with similar climatic parameters (using an accuracy of +/-5%). We then reversed the analysis to identify the climatic envelope for Demo Dairy’s location using 2070 climate datasets and identified locations in the current climate dataset presenting similar conditions.

The outputs from this analysis were then exported into KML to create our second visualization (Figure 3).

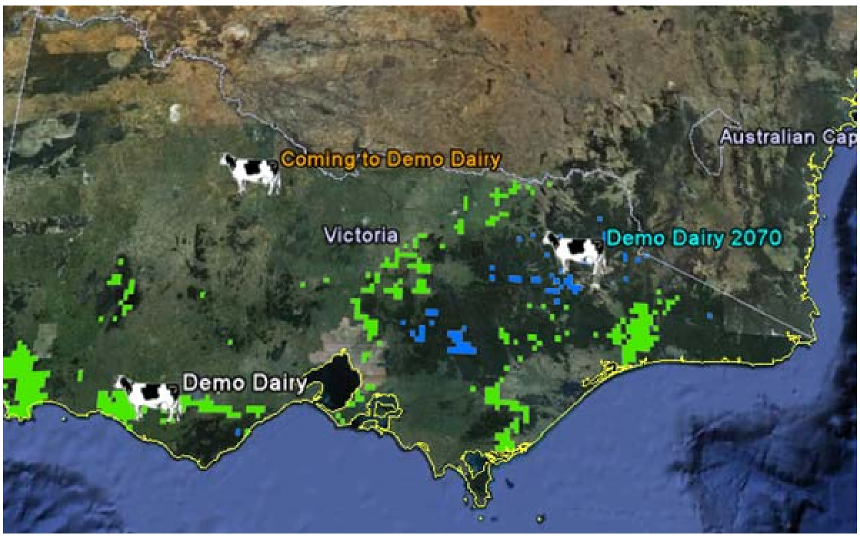


Figure 3. Illustration of the “moving farm” visualization.

(ii) 3D realistic images and panoramas

Photo-realistic visualizations have been shown, in the urban planning context, to provide a helpful support to allow people to relate and better engage with proposed land use changes. We trialled the use of a combination of 3D objects and realistic panorama interfaces within our climate change visualization to evaluate if and how they could help our stakeholders better understand and relate to climate change.

We designed two products, later brought together into the Google Earth interface, to provide a higher level on realism and contextualization to our data visualizations.

The first element was composed of 3D objects of the Demo Dairy farm buildings, fences and trees (Figure 4) (initially developed 3D Studio Max from building photos and measurements and later converted to KML format). These elements were designed to provide a familiar background to the climate change data exploration part described above, and help people relate their farm to the presented datasets in a spatial context.

Figure 4. Illustration of 3D objects used to provide a realistic background to climate change data visualisations.

The second component was developed as a virtual panorama depicting the Demo Dairy farm under current conditions (Figure 5a) and what it could look like under future climate conditions (Figure 5b). We used the software 3dnature Visual Nature Studio to develop these panorama images that were later incorporated into Google Earth as “Street View” interactive panoramas and imbedded in the virtual landscape at their specific location. Figure 5a, depicting current conditions, was developed using information on current practices and photos from the farm (to define pasture and crop types, stocking rates, vegetation stages, etc.). Figure 5b, which aimed at representing future conditions, would have required inputs from multiple predictive models applied locally. However, this type of data is not yet available and we presented an “artist view” of what conditions could look like under a dryer climate. This representation, not directly based on scientific data, was used to present the potential of this type of tool, and will be replaced by outputs based on projected data in further developments.

a  b 

Figure 5. Screenshot of virtual realistic panoramas illustrating (a) the Demo Dairy farm under current conditions and (b) what a dryer future could look like.

The aim of these 3D realistic panoramas was to provide farmers a window on potential futures and show them what things may look like, in a familiar environment, under different climate change scenarios and adaptation options. We believe this type of visualization has the potential to communicate a large amount of scientific data in a "language" farmer and local communities can easily understand and in a context they can relate to.

(iii) Online videos

All of the above described visualization products were developed to be incorporated into Google Earth as a virtual Demo Dairy interactive environment where users could move freely and explore the climate change projection and impact datasets provided.

However, the use as such an interactive environment may be challenging for some users who may not be comfortable with the technology or may get lost in the immensity of the Google Earth inbuilt dataset.

To alleviate some of these risks and allow users a chance to view the developed products without making use of the digital globe environment, we created videos of each of the component of our virtual Demo Dairy interface.

Making use of pre-recorded videos allowed us to guide viewers through the developed interface and show its full extent and potential. These videos could also be used as demonstrations before users be given access to the KML interactive visualization (as they may otherwise overlook some features). These videos were later uploaded on YouTube and other online hosting sites to make them easily accessible from anywhere over the internet.

(iv) Web page

Over the last 10 years the access and use of internet based technology has exploded and most people now connect to the internet to access the World Wide Web on a daily basis. To provide a point of access that our stakeholders could visit to view and download the climate change visualization described above, we developed a Web page of our Virtual Demo Dairy (Figure 6). This Web page was designed to provide a front end to our climate change visualization products where farmer could obtain information relative to our project, view some of the images and videos produced and download our interactive KML interfaces (the web page can be accessed at http://www.dpi.vic.gov.au/vro/demodairy). The use of a web page a "one stop shop" to our visualization products was valuable for the following reasons:

(1) It allowed our stakeholders to have access to and view our data visualization products from any computer and at anytime of their convenience. This is particularly important for farmers which working schedule and geographical isolation do not always allow them to attend facilitated workshops where this type of information would traditionally be presented.

(2) By providing access to data over the internet we could provide stakeholders data that could be updated at anytime and could also easily be shared from farmer to farmer. This also avoided the use of permanent data support such as CD or DVD which can be damaged or lost.

(3) Our web page was hosted within the official Department of Primary Industries website (the Victorian Resources Online) which provided our stakeholders an indication of the source and trustability of the data presented in our visualizations.

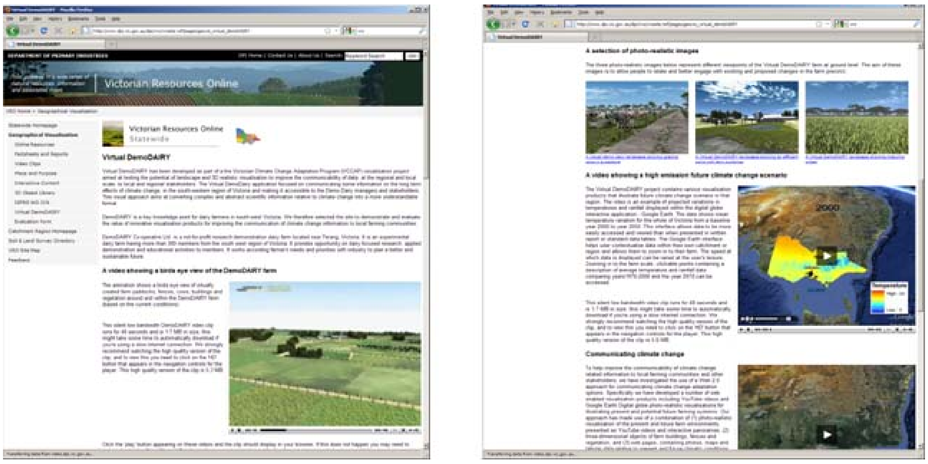


Figure 6. Screenshot of the Virtual Demo Dairy Webpage.

Results and User's response

The data visualization products described above were made available online and presented for feedback to a group of 20 Demo Dairy stakeholders during a half day facilitated workshop. The data presented here corresponds to early learning and comments obtained during the workshop.

Results from a detailed user evaluation questionnaire are currently being analysed and will be the object of a further publication.

Stakeholder workshop

We presented our climate change visualization products via a facilitated stakeholder workshop. Workshop attendees were first given a demonstration of the interactive Google Earth visualizations and were then given the opportunity to interact with them either using a touch table screen or a conventional mouse and keyboard computer interface. Overall, the workshop was well received and stakeholders provided us with positive feedback and comments such as: “this will be one of the best ways to reach people with little understanding of the big picture issue of climate change - bring down to the local level and situation” and “ Seeing is better than just reading”.

However, not all components of the presented visualizations were equally well received. The “data exploratory interface” and the “moving farm” presentation received mostly positive feedback. We received comments such as “being able to zoom in on an area/farm and see future projection of rainfall/temp is very good for making all the talk and information real and relevant to one person” and this tools “puts things into a tangible perspective. You can better imagine data in how it applies at a current place and time”. Some users also pointed towards the potential use of these tools in future farm planning.

On the other hand, people were divided on their perception of the value as for the 3D contextualization components and immersive panoramas.

A proportion of our stakeholders were very critical providing comments such as “I don't really think that visualizing farm layout in 3D can help a farmer when they can see and understand their property by simply looking at it in real life” or “I suspect farmers would find it difficult to use and a bit of a waste of time”.

However, some stakeholder felt more positively in regard to these tools indicating that, “these make the whole thing more realistic, short of actually going into the paddock” and “the visualization makes the info have impact and it’s quick to interpret. I think it is something people can relate to and may take it more seriously”

Our visit to rural Victoria during the workshop also highlighted some issues regarding the capacity of our stakeholders to get access to high speed internet or download large files. Low internet speed led some of the visualization to display very slowly which made some farmers lose interest in the products. We will therefore consider the use of CD or DVD support in the development and circulation of future visualization.

Stakeholder access to the online Virtual Demo Dairy web page.

The virtual demo dairy web page presented a description of our climate change visualization project and links to view our online descriptive videos and download the developed KML interfaces. It was made available online a week prior to our stakeholder workshop and internet traffic to this page was recorded for a month following the workshop. Overall, the virtual Demo Dairy web page received 147 unique visitors who stayed an average of 3 minutes 14 seconds. This average time-per-page statistic was over three times higher than the average for the Victorian Resource Online website which could suggest that this type of visualization may be of high interest to farmers and other stakeholders. However the viewing of videos and downloading of KML files were not monitored and therefore limits our capacity to further analyse viewer's preferences.

Conclusion

We developed and tested a combination of innovative visualization products to help communicate climate change projections and impacts to farming communities. Our use of digital globe technology, photorealistic images and online videos aimed at bridging the gap between scientists and the farming community by translating data usually presented as "indigestible" paper reports, tables or static maps into a more understandable and locally relevant format.

The developed visualizations were presented at a stakeholder workshop which, while indicating positive reactions towards the use of such technologies, highlighted that not all of the tested technologies had the same potential and that some audiences may be more receptive to certain visualization methods than others. Further testing and evaluation is now being conducted to identify the appropriateness of each visualization method to communicate scientific data and determine which audience it may best be suited for.

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