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# Cloud Data and Computing Services Allow Regional Environmental Assessment: A Case Study of Macquarie-Castlereagh Basin, Australia

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**Abstract:** Large amounts of data at various temporal and spatial scales require terabyte (TB) level storage and computation, both of which are not easy for researchers to access. Cloud data and computing services provide another solution to store, process, share and explore environmental data with low costs, stronger computation capacity and easy access. The purpose of this paper is to examine the benefits and challenges of using freely available satellite data products from Australian Geoscience DataCube and Google Earth Engine (GEE) online data with time series for integrative environmental analysis of the Macquarie-Castlereagh Basin in the last 15 years as a case study. Results revealed that the cloud platform simplifies the procedure of traditional catalog data processing and analysis. The integrated analysis based on the cloud computing and traditional methods represents a great potential as a low-cost, efficient and user-friendly method for global and regional environmental study. The user can save considerable time and cost on data integration. The research shows that there is an excellent promise in performing regional environmental analysis by using a cloud platform. The incoming challenge of the cloud platform is that not all kinds of data are available on the cloud platform. How data are integrated into a single platform while protecting or recognizing the data property, or how one portal can be used to explore data archived on different platforms represent considerable challenges.

**Keywords:** regional environment assessment; cloud platform; Google Earth Engine (GEE); land use; Macquarie-Castlereagh catchment

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## 1 Introduction

Regional environmental analysis and assessment are generally aimed to understand the current situation and changes and to assess the environmental consequence of a plan, policy, programme, human activities, and decisions. Regional environmental analysis and assessment is an evaluation of the effects likely to arise from a significant action significantly affecting the environment (Jones and Grant, 2001; Jay et al., 2007). Carrying out a comprehensive assessment requires the support of enormous spatial and temporal datasets, such as land cover, water and vegetation parameters (Olagunju et al., 2017). Land cover and land use change is a critical parameter representing the regional conditions of social, economic and environmental status (Brown, 2013). For example, surface water and related ecosystems, including river, streams, lakes, reservoirs, and wetlands, are the primary habitat provider for most species on Earth. In the meantime, surface water can adequately reflect the water supplied to the ecosystem, agriculture, and human activities; however, it is easily affected by the human activities and climatic factors. Vegetation parameters, such as extent and vegetation condition indi-

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ces, characterizes ecosystem status while their responses to environmental changes are critical signs for appropriate management decisions (Kong, 2016). Understanding the spatiotemporal patterns of these parameters, as well as their interactions, provides critical information regarding the current environmental status and is vital for management interventions for improving environmental function and ecosystem services (Macpherson et al., 2013). Various natural and human activities can impact the regional environment, creating difficulties for environmental managers. Hence, expanding the environmental management to the regional level can help environmental managers have a broader vision and obtain more information to generate a better plan for decision makers.

Traditionally, extracting information from Earth Observation System (EOS) data is not a trivial task due to the volume and variety of the data. For instance, datasets from different disciplines are usually acquired and collated by various departments with varied methods. Manipulating multiple large-scale spatial datasets, such as land cover and land use, water surface, vegetation cover and other environmental data typically requires considerable financial and time overheads (Friess et al., 2011). This is one of the reasons that data producers are not willing to share their data with others. Moreover, much of the environmental data is siloed in different platform or systems in the producers' department or website with different formats. Traditionally, it was difficult to integrate them into a specific research topic in a particular area. The fast development of earth observations systems further complicated the situation by continuing collection and accumulation of data which offered researchers more high-quality data covering larger regions but raised new challenges, such as: data consistency (between data from previous platforms with coarse resolution and data from most recent platforms), data storage, processing algorithm and computation capacities (Friess et al., 2011; Padarian et al., 2015; Lewis A et al., 2017).

The emerging concept of 'cloud' and rapidly developing technologies offer an alternative and effective method to solve this problem. Cloud platforms have played an essential role in facilitating public access to geospatial analysis and simple spatial analysis tools (Friess et al., 2011). Cloud platforms are capable of storing a significant amount of data and smoothly integrating temporal and spatial data. The cloud platform can also provide data and computing services for the users who do not have any data, reducing the threshold of researchers to customize their datasets. There are many publicly accessible cloud platforms, such as Google Earth Engine (GEE), DataCube, Sentinel-hub (https://sentinel-hub.com), Amazon Web Services (AWS) (www.aws.amazon.com), and OpenStreetMap (www.openstreetmap.org) (Padarian et al., 2015). Once an algorithm or application has been developed on a cloud platform, users can produce data products or deploy new applications without extra investment.

GEE is one of the online cloud platforms for environmental analysis. GEE contains a multi-petabyte catalogue of satellite imagery and geospatial datasets with planetary-scale analysis capabilities that are available for scientists, researchers, and developers to detect and quantify changes on the Earth's surface (Gorelick et al., 2017). GEE is mainly used for generating new dataset across a variety of disciplines, covering topics such as global forest change (Hansen et al., 2013), global surface water change (Pekel et al., 2016), cropland mapping (Xiong et al, 2017), flood mapping (Tang et al., 2016) and oil palm plantation (Lee et al., 2016). GEE has also been integrated into some third-party applications, for example, assessing land use change (Collect Earth, 2016), soil mapping (Padarian et al., 2015), and crop yield estimation (Lobell et al., 2015). Data stored in GEE provides a new approach for integrated analysis; however, its application with independent datasets for specific research objectives is less discussed.

At the same time, Australian Geoscience DataCube aims to be a platform for resolving the problems of increasing earth observation data and promoting earth observation data analysis technologies for Australia (Lewis et al., 2017). The DataCube provides efficiently calibrated and standardized datasets (e.g., more than 300 000 images from Landsat satellites since 1986), enabling the application of time series with quantities information products (Wang, 2017). Water observation is one of the forms based on the DataCube (Mueller et al., 2016). 'Best available pixel composites and temporal statistics' is another application. The DataCube also helps researchers to combine data from different sources to generate water quality observation with time series (Mueller et al., 2016). Other datasets, such as the Australian fractional cover and land use datasets, are all stored in the DataCube system; however, the data focus is on the Australia domestic case and thus have fewer applications and products than the GEE.

In this research, we explore the potential of cloud data storage and services as a low-cost and accessible regional environmental assessment tool. We selected the Macquarie-Castlereagh Basin, New South Wales, Australia as the experimental area of study. This area has multiple land cover types with agriculture, wetland and mountain valleys. The purpose of this paper is to validate if different data types like land use data, water surface data and NDVI data can contribute to the estimation of land cover change. Estimating the land use change and their drivers, particularly water availability in a Macquarie-Castlereagh Basin has strong effects on decision making of enhancing the regional resilience to drought.

## 2 Materials and Methods

### 2.1 Study area

The Macquarie-Castlereagh Basin is located at the intersection between Cudgegong and Orange, central-west of New South Wales (NSW), Australia. The Macquarie-Castlereagh Basin is a watershed in the Murray-Darling Basin (MDB). The total area of the region is over 90 000 $km^2$. The boundary data of Macquarie-Castlereagh collected from 'Australia's River Basins 1997' (https://data.gov.au/dataset/australias-river-basins-1997) produced by the Geoscience Australia.

Agriculture dominates land use in the Macquarie-Castlereagh, over 80% of the land is used for grazing, cropping, and horticulture. Dryland grazing is the most extensive land use for livestock to produce cattle and sheep. The dominant irrigation type is rain-fed. Approximately 77 500 ha were irrigated land in 2000, with 52 400 ha of land for cotton. The dynamic nature of the land covers makes this region attractive for time series analysis.

The Macquarie Marshes is Macquarie-Castlereagh's most significant wetland system. The Macquarie Marshes is a national wetland and has been recognized as Ramsar-listed because of its unique ecosystem, with the focus of managed environmental water. The characteristic of the Macquarie Marshes is that the marshes are frequently flooded to maintain the ecosystem health. Rare species, such as Rare species, such as River Red Gum (*Eucalyptus camaldulensis*) and some water birds rely on frequent inundation for breeding. The Marshes includes a range of wetlands, such as reed beds, water couch meadows, river red gum woodlands, and floodplains, which are inundated by only massive floods.

### 2.2 Data and processing

Two land use datasets were used in this study. One dataset is New South Wales Land Use Data 1999–2006 (https://data.nsw.gov.au/data/dataset/nsw-foundation-spatial-data-framework-land-cover-land), which is raster data covering the period of 2000 to 2007 at a 1 ∶ 50 000 scale and those for two counties of Cudgegong and Orange were at a 1 ∶ 25 000 scale. the data were acquired in 2006 by the ALUM version 7 in the Macquarie-Castlereagh Basin in the NSW land use data 1999–2006. The datasets were stored in the Australian Geoscience website and can be downloaded freely (http://www.agriculture.gov.au/abares/aclump/land-use/data, last accessed: 29/01/2019). The other dataset is the Catchment Scale Land Use Data of Australia from 2014 to 2016 at a resolution of 50 m on a national scale (http://data.daff. gov.au/anrdl/metadata_files/pb_ luausg9abll20171114_11a.xml). The Macquarie-Castlereagh Basin mapping date is collected since 2014 at scales of 1 ∶ 10 000 and 1 ∶ 25 000 to show the land use change from 2007 to 2014. The Catchment Scale Land Use Data are stored in the Australian Government online portal and can be freely downloaded (https://data.gov.au/dataset/catchment-scale-land-use-of-australia-update-march-2015, last accessed: 29/01/2019). The specific land use includes conservation areas which are concentrated in the upper central of the region, of which most is wetland. Forestry is distributed in the east and south of the region. Cropping and grazing areas are distributed in the western and central of Macquarie-Castlereagh Basin. Other land use types include water body, urban intensive use, transport, mining and other blurred landcover types for classification system.

Vegetation fractional cover (VFC) is an essential factor for environmental impact assessment. VFC refers to estimate the proportion of a region covered by vegetation which is derived with linear unmixing methodology by Guerschman et al. (2015). This data was processed from MODIS (Moderate Resolution Imaging Spectroradiometer ) Terra and Aqua data. VFC datasets are downloaded from DataCube (http://geoscienceaustralia.github.io/digitalearthau/notebooks/02_DEA_datasets/Introduction_to_Fractional_Cover.html) and uploaded to GEE in this research. The change rate is generated through a geomatics calculator on the GEE platform. Vegetation fraction data present a time series used to derive the change in the fractional cover through the geo-calculator. The normalized difference vegetation index (NDVI) is an indicator to present the vegetation's vigor, including health, quality, and the productivities and the data source comes from Landsat series. Weacquire NDVI data from the GEE 'dynamic' analysis. The pixels are selected for the land use classes of the study area. The GEE editor computes the annual maximum NDVI data of selected pixels from Landsat data directly. The NDVI and VFC both have the same resolution as that of the Landsat data, and can be used to understand the condition of plant in the experiment area.

European Commission's Joint Research Centre (JRC) uses the entire multi-temporal orthorectified Landsat 5, 7 and 8 archive spanning the past 32 years to map the spatial and temporal variability of global surface water and its long-term changes (freely available from https://global-surface-water.appspot.com/) at 30-m resolution (Pekel et al., 2016). In this research, we used the global surface water data to show the water surface area and how long the water will be present. The annual history water surface data are assigned four values of 0, 1, 2, and 3 that correspond to no observation, not water, seasonal water and permanent water, respectively. A stable water surface is underwater throughout the year, whereas an annual water surface is underwater for less than 12 months of the year. The water surface area is a useful metric to compare with the water count data.

The water count product is calculated per pixel as the sum of the number of observations with water present across the Landsat time series as a fraction of a total number of possible views in the 25-yr period (1 January 1988 to 31 December, 2012). The product has two bands: band 1 is the number of times water was present across the time series, and band 2 is the count of unobscured (i.e., non-null) input pixels, or some total observations for that pixel. Cloud, cloud-shadow, steep slopes and topographic shadow can obscure the ability to count water presence (Danaher et al., 2006; Fisher et al., 2016).

### 2.3 Google Earth Engine (GEE)

Detailed patterns of changes in land use types were calculated using conversion matrices to track 'round-trip' changes in each land-use type (Rhemtulla et al., 2007). The land use transfer matrix is a mathematical approach to illustrate the land use transfer from an old classification to the new classification. The transfer matrix shows the complex paths that may exist in changing land use and can, therefore, help identify potential direct land-use change impacts. The matrix provides data as a net change in a class by taking into account differences in 'from and to' changes.

In the meantime, water surface and water count products from GEE will be integrated into the landuse change. We summarized the changes of seasonal and permanent surface water in the last 15 years. Land use change drivers were identified by integrating the surface water change and land use change data with vegetation condition and extent as a proxy of farmland quality. This permitted the drivers and impact of water availability on land use to be determined. This framework enabled the GEE cloud service to be comprehensively evaluated in the context of regional land use change attribution.

## 3 Result and Analyses

### 3.1 Land use change

Table 1 shows that 155.78 $km^2$ (2%) of forestry area transferred to the grazing modified pastures area which may shows a deforestation process. The transfer matrix shows that a small amount of the cropping land was used for the reservation, and the little high-quality land was transferred into the cropping region. In this research area, conservation area was always deeply concerned by governments, Non-Governmental Organisations (NGOs) and publics. In the meanwhile, the conservation area and the land use are not always in the same definition by differet institutes. Fig. 1 and Table 1 show that there is a large conservation area transfer to the forestry in the middle-subsequent area of the Macquarie-Castlereagh Basin which is driven by the complex definition of the conservation area and the applicable land and it brings potential damage to the local ecological system. For example, the Ramsar system defined the Macquarie Marshes have 2000 $km^2$. It was recognized internationally and has been confirmed by the New South Wales

Office of Environment and Heritage in Department of Water. On the other hand, the conservation area of the Macquarie Marshes was less than 200 km$^2$ defined by the New South Wales National Parks and Wildlife Service and the 200 km$^2$ was also been illustrated in the land use data set. This is caused by the differences of classification definition. New South Wals Parks and wildlife service defined the constant wetland as the conservation area. The New South Wales Office of Environment and Heritage of Department of water defined long-term inundation area as the conservation area which is different from the definition from New South Wales National Parks and Wildlife service. Due to change of classification method, conservation area decreased approximately 64.84% with an area of about 2948.02 km$^2$ from 2006 to 2014, 45.02% of the conservation area moved to the forestry by 2046.94 km$^2$. Macquarie Nature reserve was an international well-known park that has been well developed and protected by the human and it is a critical conservation area in the Macquarie-Castlereagh Basin. However, more than 1800 km$^2$ inundation region area around the reserve region was not under well managed and maintained, which is flooded in the flooding season frequently. The floods are a nature performance process of the Macquaire Marshes that can keep feeding the rare species like *Eucalyptus camaldulensis* roest. Those areas were neither developed nor defined as conservation area but was the most important part of the wetland ecosystem. Approximately 5169.70 km$^2$ (83.26%) of forestry and 852.57 km$^2$ (18.75%) of the conservation area transferred to the minimal use such as defense land, stock route, residual native cover, and rehabilitation use. This is caused that non-conservation area has potential to be developed by local institutes.

### 3.2 Vegetation cover change

Fig. 2 shows the vegetation cover change rate from 2006 to 2014. We can see that the vegetation cover is deep green which means vegetation cover significantly increased in the Macquarie Marshes where is the conservation and wetland area concentrated in the middle of the map. In the mean time, the majority of the vegetation cover increased slightly since 2006 and most of the area are the grazing and cropping area where among the western and northern of the basin. Those changes can be confirmed from the Fig. 1 and Table 1 that forestry has decreasing from 2006 to 2014. In contrast, the vegetation cover decreased in the east and the southern regions where the main landscapes are tree and horticultures.

Fig. 3 shows the change of NDVI value for main land uses in the Macquarie-Castlereagh Basin. The curves show that horticulture has highest NDVI value due to the drainage system. Conservation area has the second highest value in the samples where was benefit from the well-managed wetland ecosystem area. . The trees and shrub cover have the third highest amount. The grazing and cropping area has a lower NDVI value rather than other three land use types. Forestry area's NDVI value has significantly increased since 2006 and decreased since 2010. Those areas were well maintained. The grazing and cropping area had the lowest NDVI. Both of

**Table 1** Transfer matrix of land use from 2006 to 2014 at the Macquarie-Castlereagh Basin (km$^2$)

| Land use type | Conservation area | Forestry | Grazing | Cropping | Horticulture | Urban intensive use | Transport | Mining and waste | Water | Other minimal use | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Conservation area | 1598.51 | 2046.94 | 19.76 | 6.00 | 0.15 | 14.72 | 0.22 | 0.16 | 7.49 | 852.57 | 4546.53 |
| Forestry | 1.80 | 679.87 | 155.78 | 10.89 | 0.06 | 5.05 | 179.34 | 0.42 | 5.84 | 5169.70 | 6208.73 |
| Grazing | 2.85 | 32.25 | 60140.44 | 183.26 | 2.81 | 103.30 | 411.04 | 1.47 | 129.58 | 119.50 | 61126.51 |
| Cropping | 0.19 | 8.49 | 172.04 | 17110.20 | 0.21 | 35.06 | 0.51 | 0.12 | 35.95 | 4.85 | 17367.63 |
| Horticulture | 0.02 | 0.11 | 3.37 | 0.25 | 100.35 | 0.89 | 1.14 | 0.00 | 0.42 | 0.06 | 106.62 |
| Urban intensive use | 0.11 | 0.14 | 4.56 | 0.46 | 0.13 | 249.57 | 0.05 | 5.74 | 1.00 | 0.83 | 262.59 |
| Transport | 1.10 | 4.12 | 149.10 | 39.61 | 0.53 | 532.95 | 0.80 | 0.24 | 1.87 | 20.56 | 750.88 |
| Mining & waste | 0.06 | 0.19 | 2.65 | 0.21 | 0.00 | 0.36 | 11.07 | 36.80 | 0.07 | 13.72 | 65.13 |
| Water | 0.13 | 0.23 | 25.01 | 5.29 | 0.16 | 251.37 | 0.38 | 5.74 | 93.68 | 9.20 | 391.21 |
| Other minimum use | 0.00 | 0.08 | 12.51 | 4.48 | 0.03 | 1.73 | 0.25 | 0.00 | 1.17 | 8.05 | 28.31 |
| Total | 1604.77 | 2772.35 | 60672.73 | 17356.17 | 104.40 | 1193.27 | 604.56 | 50.70 | 275.91 | 6190.98 | 90825.82 |

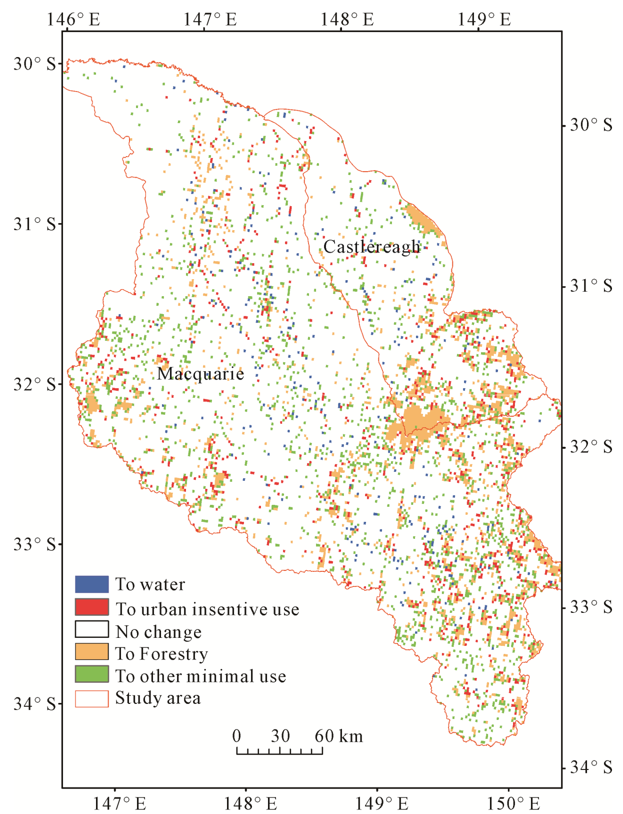


**Fig. 1** Land use change at the Macquarie-Castlereagh Basin from 2006 to 2014, Austrilia

the grazing and cropping area has low NDVI value caused by the effect of the millennium drought and it is confirmed by the local rainfed drainage method. Some of the grazing area was transferred to the minimal use for the water saving or fallow.

### 3.3 Water surface area change

Fig. 4 shows the change in the water surface area. The seasonal water supplement is much more than permanent water. In the meantime, seasonal water also had a higher amplitude of change than permanent water in different years. The permanent water kept a stable supplement from 1999 to 2010 and rapidly decrease after year since 2010. Since July 2012, precipitation in the catchment has been well below average, with Burrendong Dam inflows below the 80th percentile (State of NSW and Office of Environment and Heritage, 2016).

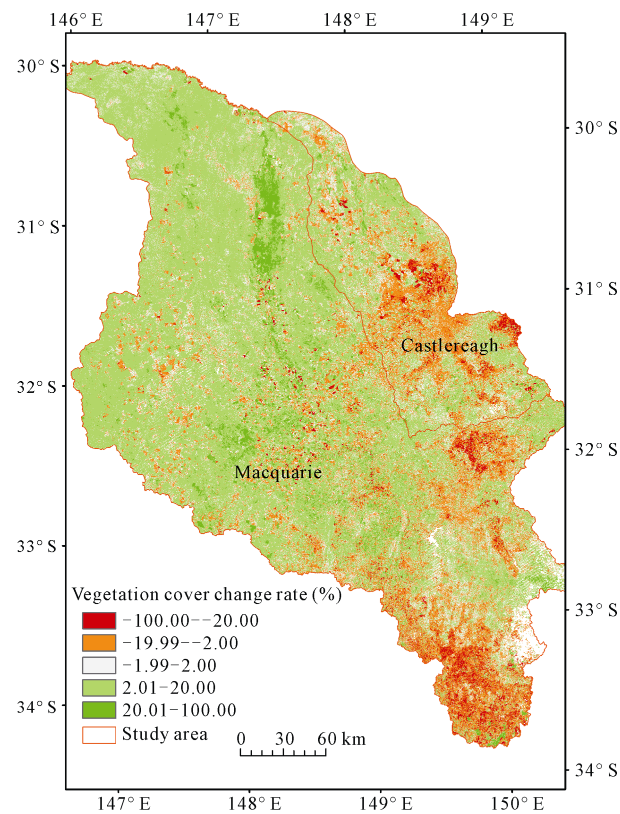


**Fig. 2** Vegetation cover change rate (%) from 2006 to 2014 at the Macquarie-Castlereagh Basin, Austrilia

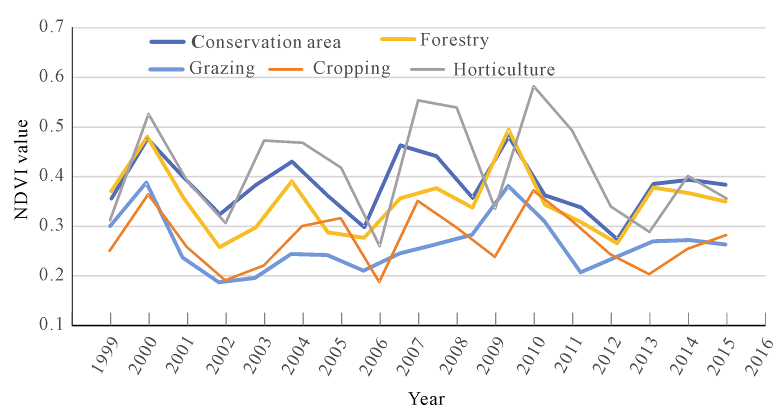


**Fig. 3** Change in the NDVI values of specific land-use type at the Macquarie-Castlereagh Basin from 1999 to 2015

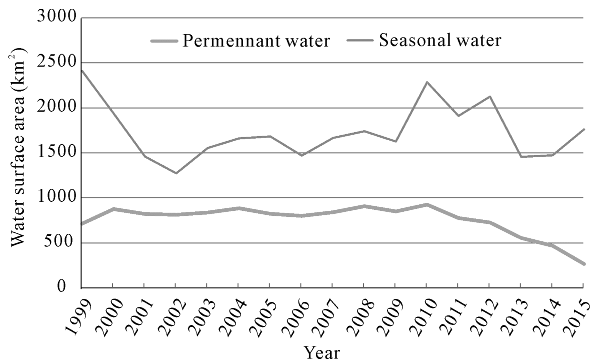


**Fig. 4** Change in the water surface area at the Macquarie- Castlereagh Basin from 1999 to 2015

This can explain why the permanent water surface decreased since 2010. Those disappeared permanent water might be transferred to increase the water supplement for irrigation area which is the Burrendong Dam designed for. Table 1 can confirm above assumption that Macquarie-Castlereagh Basin had 5.29 km$^2$ (1.35%) and 25.01 (6.39%) of water area transferred to cropping and grazing area and another 251.37 km$^2$ (64.25%) of water transferred into urban area which is effected by the minimized water surface from huge fammer's requirement extraction from river and storage water. The permanent water surface decreased from nearly 1000 km$^2$ in 2006 to lower than 500 km$^2$ from 2010 to 2014.

Fig. 5 shows the amount of water surface appearance since 1984. The west of the Macquarie-Castlereagh Basin was dry and no permanent and frequent water surfaces are observed in that area. Macquarie Marshes had frequent water surfaces because it is wetland conservation area. The wetland did not exhibit a permanent water surface because the wetland could be covered by the *Phragmites australis* and other forms of water-favor vegetation. The vegetation can block the water surface from the satellite sensors and the wetland water surfaces only appear during the high-water-level season like flooding season. The primary permanent water surfaces in the Macquarie Castlereagh region are Lake Burrendong and Lake Windermere. Other small permanent water surfaces are not visible on a small map.

### 3.4 Integrative analysis

GEE offers an integrative analysis environment of land use, vegetation, water and their changes. Previous research showed that the water surface can transfer into other land use types. In addition, the health of vegetation relies on the rainfed or seasonal water supplement. Hence, we can assume that there are relationships between health of vegetation and nearby water supplement. Health of vegetation can be assumed through the value of NDVI and the water supplement can be measured through permanent and seasonal water data. In this scenario, we build up the Fig. 6 which integrated all NDVI and water supplement data for each land use class over time. Both NDVI and seasonal water values reach their minimum values in 2002 and enter their highest values in 2010. In general, NDVI values have close relationships with seasonal water rather than permanent water for most land use types, except horticulture.

Furthermore, we calculated the linear relationship (Table 2) among NDVI values of all land use types and the different water supplement methods. The maximum of $R^2$ among water and NDVI value was less than 0.4 which is a low value. This result shows that permanent and seasonal water area did not have direct relationship with vegetation growth in Macquarie-Castlereagh Area. However, Fig. 6 has a different answer. NDVI values from different vegetation covers has similar movements as water cover under one time-series. This means,

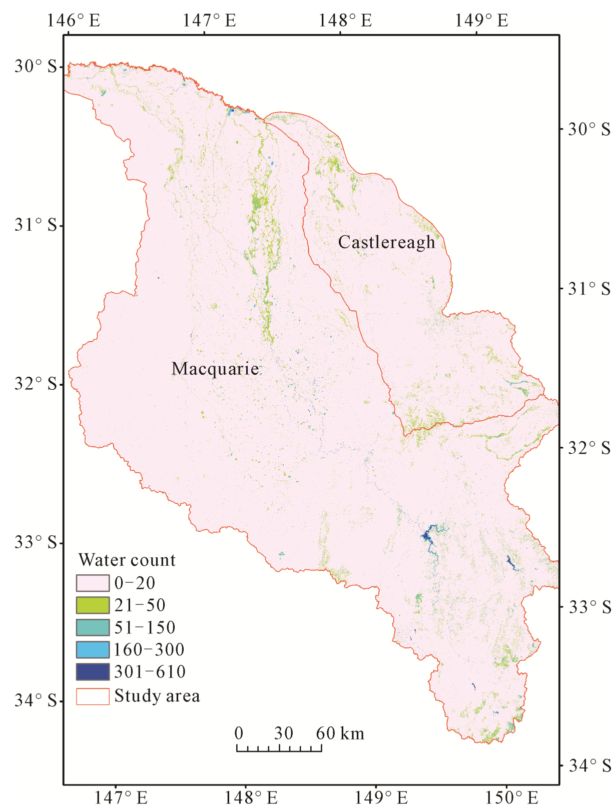


**Fig. 5** Amount of water surface appearance from 1984 to 2015 at the Macquarie-Castlereagh Basin, Austrilia

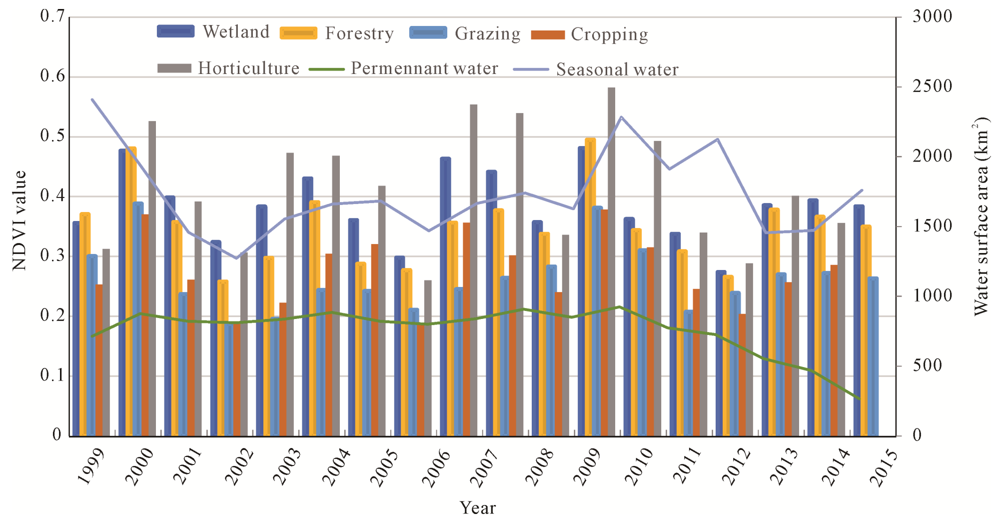


**Fig. 6** Change in the annual maximum NDVI value of the main sample vegetation covers and the water surface area at the Macquarie-Castlereagh Basin

**Table 2** $R^2$ values of the relationship between the NDVI values of different land use types and permanent, seasonal water surface areas

| Water class | NDVI | | | | |
|---|---|---|---|---|---|
| | Conservation area | Cropping | Horticulture | Forestry | Grazing |
| Permanent water | 0.1194 | 0.0776 | 0.2050 | 0.0331 | 0.0119 |
| Seasonal water | 0.1221 | 0.2561 | 0.0877 | 0.3273 | 0.3885 |

vegetation growth and water cover has a relationship in the time-series scale. However, this research didn't locate the representative of this relationship. Locating the formula or indicators between the vegetation growth and water cover could be a target in the future research.

## 4 Discussion

The focus of this study is to demonstrate the potential use of a new cloud-based framework for environmental analysis. The cloud tools such as GEE and DataCube allow users to generate accurate cover maps designed for customer applications. We have illustrated the following cloud computing capabilities: the building transfer matrix of land cover/land-use change; computing NDVI and water surface value on-the-fly and water count. All processing steps are performed on the online platform. Researchers can receive the result from the cloud platform and perform editing and selection of the data in a local computer (Gorelick et al., 2017).

The study uses a massive amount of data. Two scenes of Landsat data cover the entire Macquarie-Castlereagh Basin. Regarding the annual maximum NDVI value calculation, at least 90 views of Landsat were downloaded and processed, given that we only process three temporal Landsat data in the growing season for each year. With cloud data and computation, no data downloading is required, with only a few lines of python codes in GEE editor being adequate to retrieve the maximum annual NDVI value. This approach saves a significant amount of time and money that would have been used to download data and to build up computation and data storage capacity.

The cloud platform allows researchers to upload their geoscience data (Gorelick et al., 2017). The cloud platform will enable researchers can integrate their personal data with the cloud data in layers with same spatial and temporal conditions, and it helps researchers to combine data on the same platform. As a result, the process of analysis becomes easy and intuitive. In this research, most of the work was operated in the GEE platform by applying the DataCube data. Data products from DataCube and GEE online data with time series are used for analyzing the change in wetland and land use in the last 15 years. Data are available for regional environmental analysis; however, only part of data are available from GEE. Water surface and NDVI indicators were generated easily from GEE. Land use/cover data, water count and vegetation fraction, were obtained from DataCube. This experience brings the following challenges to both the stakeholders and the cloud platform: data consistency in definitions of the same phenomenon by different sources, data quality assurance and uncertainty analysis, and the lack of data sources (especially for socio-economics aspects). Data must be integrated into a single platform while protecting or recognizing the data property.

Integrated analysis based on the cloud computing has great potential because it is a low-cost, efficient and user-friendly method for global and regional environmental studies. We integrate data from different sources for the Macquarie-Castlereagh Basin, which allows the interactive analysis of land use, vegetation and water for over 15 years for understanding vegetation sensitivity at land use classes to water availability. However, for review of a particular region, challenges remain to be addressed. The cloud platform requires appropriate data stewardship to ensure that data/information are useful and that standards are set for archiving new types of data through reliable and effective systems/portals and data quality control mechanism. Moreover, this research showed the integrated capacity of the cloud platform for multiple datasets on the same platform. This can help researchers integrate increasing amounts of data, e.g., evapotranspiration and climatic data, into the same platform for numerous research purposes of earth science.

Compared to the traditional method, even with limited data available, the time for Macquarie-Castlereagh Basin environmental analysis is reduced significantly. We do not need to spend time on the time-consuming tasks of downloading a massive amount of satellite data and existing products and spending time on data management. GEE also offers a function to compute NDVI and performs integrative analysis as well.

The cloud platform and methods proposed and tested in this article open the way for significant progress in developing countries by helping them build up or establish their regional analysis for their private areas of interest. Australia has a professional geoscience team for collecting and processing data. However, many countries do not have the capability of the geo-data collection, mapping, and analysis. In recent years, increasing amounts of high-resolution data have become free and open access. The cloud data access can help researchers work on the regional environmental review in the countries that lack a geoscience team. The cloud platform is not only useful for engineering purposes but also provides excellent education and training tools for researchers in developing countries. They can share and use this capacity to monitor environmental changes in their area of interest without significant investment to support sustainable development. It can be further explored to develop an application system for a specific region or domain.

The study explores the potential and challenges of the cloud platform and data for regional environmental analysis in domains such as water resource management, vegetation management, environment monitoring and assessments, especially for the large-scale and high-resolution areas (Hansen et al., 2013; Lobell et al., 2015; Gorelick et al., 2017). It has shown that GEE or any other cloud platform can be further enhanced as a regional environmental analysis platform, given that required data are available on the platform. GEE has excellent potential to perform regional analysis because it has archived the entire Landsat imagery dataset and some derived products, such as water surface data generated by JRC. When more product data become available in GEE, such as forest cover (Hansen et al., 2013) and cropland (Xiong et al., 2017), GEE can play a more significant role in regional and global environmental analysis.

## 5 Conclusions

In this research, we found that land use change in Macquarie Castlereagh Region was not too significant, about 15% of region experienced land use change from 2006 to 2015. In the meantime, we exam the effectivities of GEE and related technologies. Those methods successfully demonstrate the slight changes of land use and land cover. As a whole, the land use change was driven by the water level. The result of the growth included the less permanent water surface, higher value of vegetation change. On the other hand, human intervention and nature impact are the main drivers of the land use change in the subsequent area of Macquaire-Castlereagh Basin.

The water surface counting data shows that the decrease of the permanent water surface since 2010 had possibly been caused by shortages of rainfall or by the reduction of farm dam. In addition, results of assessing the vegetation cover change and the water surface counting show that increasing vegetation cover might be able to change the attributes of the land use. The time lag between a relative stabilization of vegetation and the movement of water level could be a possible cause of the environment variation.

The cloud platform and methods proposed and tested in this paper show a paradigm shift of region environmental analysis which the cloud platform can save computation capability and time for researchers, especially for the regional report. With cloud data and computation, no data downloading is required, even a considerable amount of data needed. Integrated analyses of vegetation fractional cover, NDVI, water count and water surface area datasets were processed interactively with time series changes for specific classes of land use on the GEE. Integrated analysis based on the cloud computing has great potential because it is a low-cost, efficient and user-friendly method for global and regional environmental studies, but data must be integrated into a single platform which raises the issues of protecting or recognizing the data property.

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