The recovery of riparian vegetation along rivers of coastal NSW since the 1980s: Implications for working with river recovery in management

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Key Points

- NDVI differences were calculated to quantify vegetation changes for the last three decades.
- About 50% of all stream length in coastal catchments of NSW has experienced an increase in NDVI values which we interpret to represent an increase in woody vegetation since the late 1980s.
- The extent of riparian vegetation recovery varies spatially and temporally among catchments which may relate to the severity and timing of vegetation clearance associated with land use change, and/or the adoption of ecosystem-based approaches to river management.
- Overall, the period 2003-2020 experienced greater vegetation increase than the earlier period 1987-2003.

Abstract

Clearance of vegetation, and de-snagging activities throughout the 19th and 20th centuries caused widespread river channel degradation across eastern Australia. However, following changes in land use and land management practices, coupled with decades of effort in river management, there has been a noticeable shift in the riparian vegetation condition of these rivers, particularly in coastal valleys of NSW. While geomorphic and vegetative recovery has been observed, we do not yet fully understand the timing and extent of recovery that has occurred. This understanding is critical to work with rivers as part of nature-based and process-based management practice. In order to understand vegetation changes in the last 33 years, we calculated NDVI difference from Landsat imageries for the time periods 1987-2003 (17 years), 2003-2020 (16 years) and for the full time period 1987-2020 (33 years). The NDVI difference was then analysed for 19 coastal catchments in NSW. The results show that 45% of stream length experienced riparian vegetation increase in the last three decades and this increase ranged from 32 to 61%. Overall, the latter period from 2003-2020 experienced greater vegetation increases than the earlier period 1987-2003.

Keywords

Riparian vegetation, vegetation recovery, Landsat, NDVI

1. Introduction

It is well recognized that human disturbance since colonisation has had a profound impact on riparian vegetation and river geomorphology in south-eastern Australia (Erskine and White, 1996; Fryirs et al., 2009). The active clearance of vegetation and de-snagging activities initiated severe river degradation which included bank erosion, incision, channel expansion, gulling and sand slug formation (Brooks et al., 2003, Fryirs et al., 2018). Historical aerial images from the 1930s to the 1940s show that many riverine landscapes contained no significant riparian vegetation.

However, since the 1970s and 1980s there has been a noticeable shift in the condition of these rivers (Hoyle et al., 2008; Rustomji and Pietsch, 2007). Revegetation of riparian zones and the placement of wood has been a focus of many ecosystem-based approaches to river rehabilitation since that time (Fryirs et al., 2013). At the same time, land use pressure has reduced, and farming practices have improved (i.e. fencing, off-river watering points). The vegetative recovery of coastal rivers in NSW is likely the result of the combined effect of these events.

At present river rehabilitation practices work with the character and behaviour of rivers and promotes nature-based and process-based management (Water UN, 2018). Detecting the degree to which these systems have recovered, and the trajectory of river recovery is now one focus for river science and management. In this paper, we undertake a preliminary analysis of the regional vegetative recovery of these systems to quantify and understand the extent to which riparian vegetation has recovered over the last three decades. We produce NDVI differences from Landsat imageries that cover the time period 1987-2020. We demonstrate the spatial and temporal variation of vegetation recovery occurred in these rivers.

2. Methodology

In order to investigate the vegetation changes over the last 30 years (Figure 1), we selected Landsat imageries from three time intervals of 1987- 1991, 1999 – 2003 and 2016 – 2020. Atmospherically corrected surface reflectance (Tier 1) of Landsat 5, 7 and 8 were acquired for each time interval through Google Earth Engine. The acquired images were masked by shadow and cloud bitmask and the median surface reflectance values of each year were calculated to minimize the effect of shadow, cloud and inner-year variation. We used NDVI difference to measure the long-term vegetation changes. The NDVI value was calculated with the yearly median value of the surface reflectance, and then averaged for each time interval (five years) to minimize the effect of inter-year variation. NDVI differences, calculated by a later time interval minus an early time interval, were used to represent vegetation changes over the last 33 years (Figure 1). Therefore, the vegetation change in this paper is a calculated measure rather than a field measurement. The processing was conducted in Google Earth Engine.

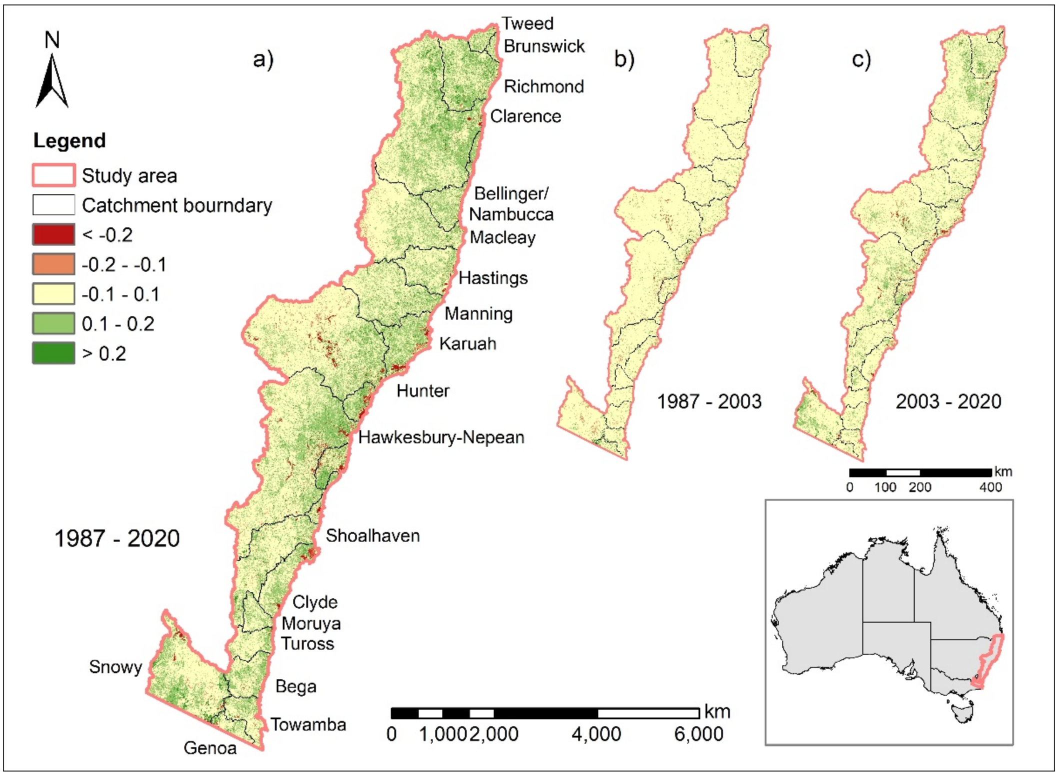

Figure 1. NDVI difference in coastal valley of NSW a) between 1987 and 2020, b) between 1987 and 2003, c) between 2003 and 2020.

The rivers in the study area were extracted from the Open Access NSW River Styles database (NSW Office of Water, 2012; Fryirs et al., 2021). A uniform 50 m buffer was applied to the stream line polyline along both sides of the line (i.e. the riparian zone). The images of NDVI difference were extracted with this river buffer polygon. A 50 m buffer is a reasonable assumption for analysis at the regional scale and is an optimal solution using current available tools. However, we recognize that this analysis is less accurate for some larger rivers and the results can be biased toward narrow channels. Further research is ongoing to select a more optimal solution to delineate the river channels and riparian zones.

To determine where vegetation change had occurred during the 33 years, vegetation increase, and decrease is represented by the increase and decrease of the NDVI value between each time interval. NDVI values range between -1 and 1, depending on the density of green vegetation. To best differentiate between different areas of change, two thresholds were applied to classify the level of vegetation change. Areas where the NDVI increased/decreased by more than 0.1 were classified as having positive/negative change and areas with more than 0.2 as having high positive/negative change. Areas with NDVI increase/decrease of <0.1 were considered as no change.

3. Results

3.1 Spatial variability in vegetation change

Based on the 5-year averaged NDVI values, long-term changes in vegetation can be detected (Figure 1). Over the full 33 years, almost all regions experienced either no change or an increase in vegetation (Figure 1-a). Areas with decreased vegetation (red spots in Figure 1) are areas of urbanization, mining, deforestation, and large water bodies which were confirmed with aerial images. There has been greater vegetation increase closer to the coast than inland. There were more areas with vegetation increase in the last 17 years (2003 -2020) compared to the previous 16 years (1987-2003) (Figure 1-b and c).

For the entire coastal region (first column in Figure 2), 45% of the total stream length has experienced vegetation increase (NDVI increase more than 0.1) and 7% of total stream length has experienced high vegetation increase (NDVI increase more than 0.2) between 1987 and 2020. About half of the stream length (52%) shows no change in vegetation. There was also considerable inter-catchment variation in vegetation changes (Figure 2). Among the 19 catchments, areas with vegetation increase ranges from 32 to 61% of the stream length and areas with high increase range from 4 to 10%. A very small proportion (only 2%) of total stream length experienced vegetation decrease. The vegetation change varied between catchments, but there was no significant trend either across the entire region or sub-region (i.e. North, Central and South region).

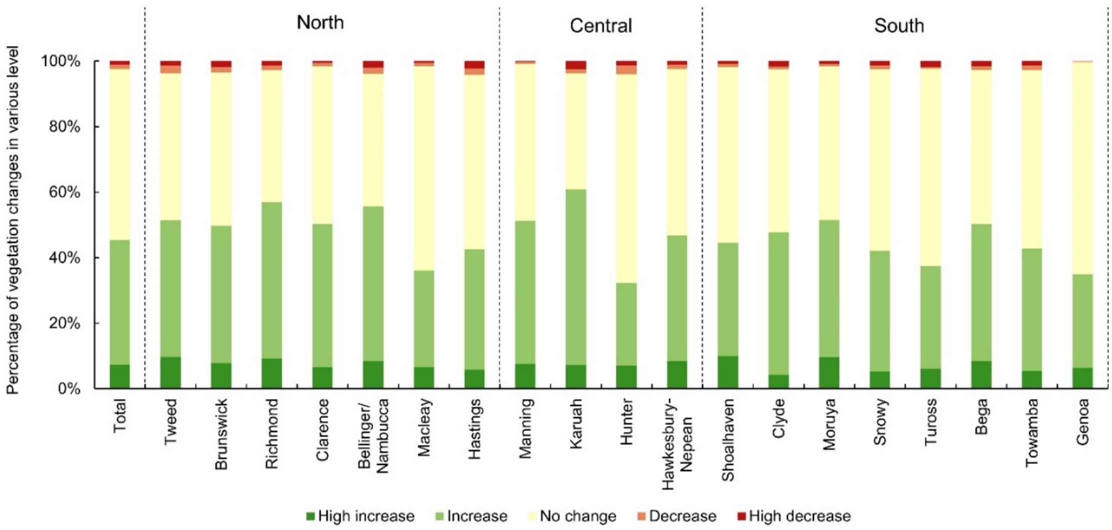

Figure 2. Predicted vegetation changes of 19 catchments in the coastal valley from 1987 to 2020 (NDVI difference more than ±0.2 was classified as high increase/decrease, NDVI difference between ± 0.1 and ± 0.2 was classified as increase/decrease, NDVI difference less than ± 0.1 was classified as no change).

3.2 Temporal variability in vegetation changes

Among the 19 catchments, 15 catchments experienced more vegetation increase from 2003 to 2020 than from 1987 to 2003 (Figure 3). For example, areas with vegetation increase in the Clarence and Snowy catchments from 2003 to 2020 were 3 - 4 times that of the area from 1987 to 2003.

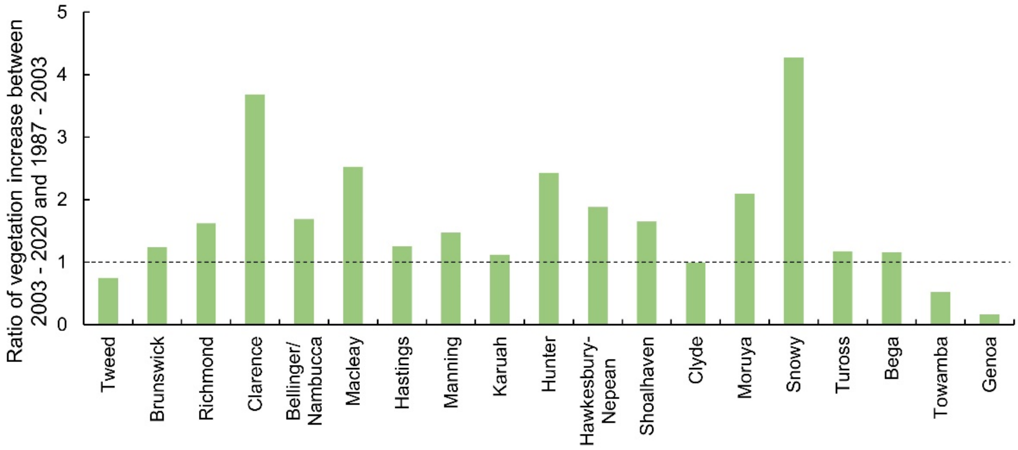

Figure 3. Ratio of the vegetation change (2003 – 2020 and 1987 - 2003).

4. Discussion

4.1 Some case study examples of vegetation changes: Bega River (south), Karuah River (central) and Bellinger River (north)

Historical aerial images provide confirmation of the vegetation changes predicted by the NDVI difference analysis. Three examples of river sections from the Bega River (south), Karuah River (central) and Bellinger River (north) are presented here (Figure 4, 5 and 6). Bega River is one river that experienced severe anthropogenic disturbance from the 19th century (Brooks and Brierley, 1997; Fryirs and Brierley, 2001). Up until the 1980s, there was still very little vegetation in the riparian zone of many streams in this catchment. The example in Figure 4-a is an example reach that occurs towards the bottom end of the catchment (Figure 4-a). In the 1987 aerial image a large sediment slug had filled a greatly widened channel with few stable channel features (Figure 4-a). Aerial images from the late 1990s show that some vegetation reappeared in the channel, which stabilized bars and benches and narrowed the active channel, but the majority of the channel bed and sediment slug is still exposed (Figure 4-b). Recent aerial imagery shows that the majority of the channel and much of the riparian zone is covered by vegetation, and flow meanders around channel features which are now stabilized by vegetation (Figure 4-c). The NDVI derived vegetation changes confirm these observations, exhibiting a high increase of vegetation in this river section (Figure 4-d).

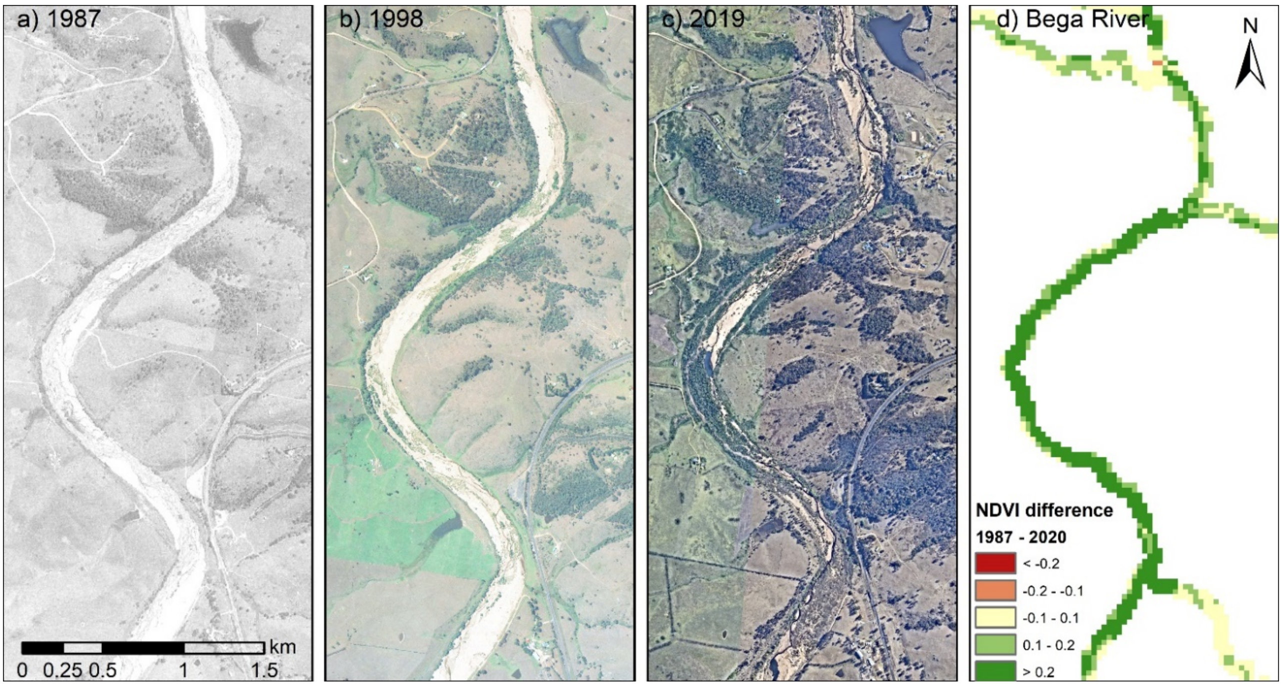

Figure 4. Vegetation recovery in a section of Bega River, a and b) historical aerial imageries in 1997 and 1998, c) recent aerial imagery in 2019 (Nearmap), d) predicted vegetation changes from 1987 to 2020.

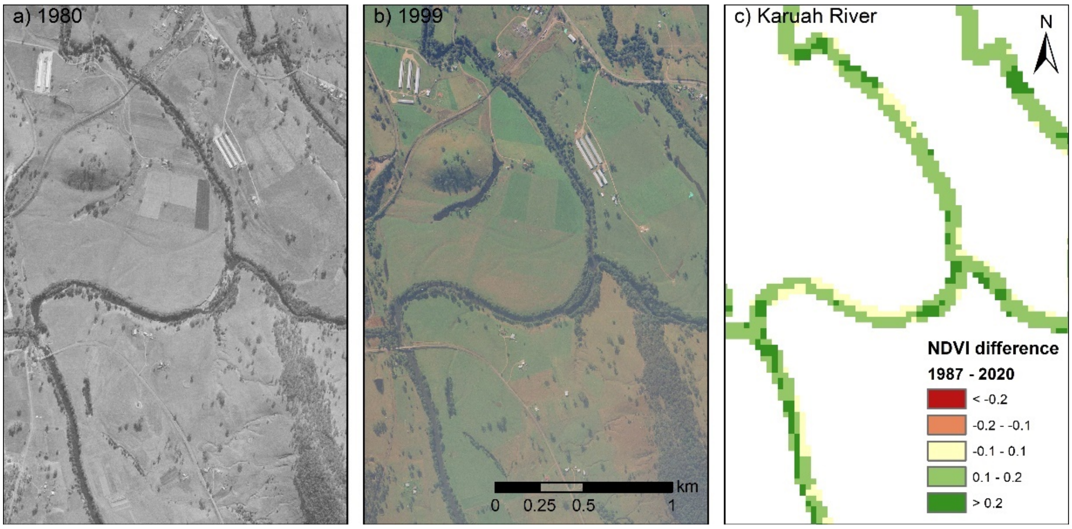

Figure 5. Vegetation recovery in a section of Karuah River, a and b) historical aerial imageries in 1980 and 1999, c) predicted vegetation changes from 1987 to 2020.

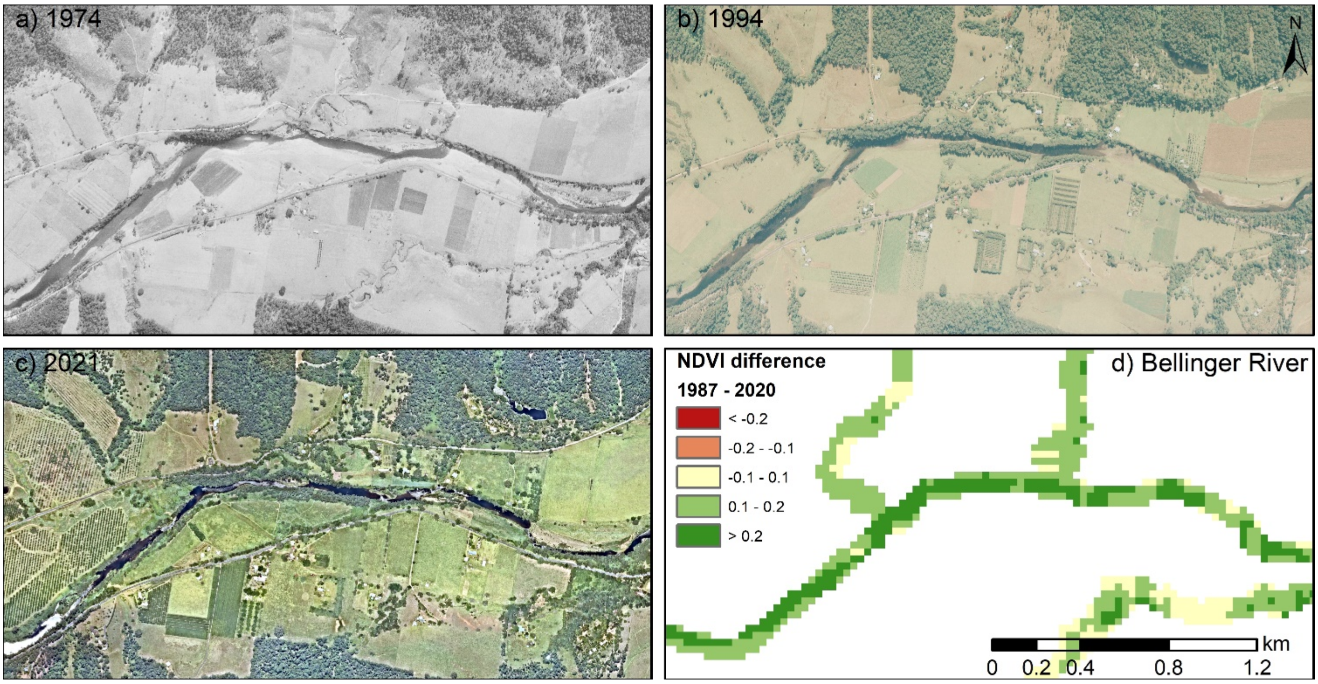

Figure 6. Vegetation recovery in a section of Bellinger River, a and b) historical aerial imageries in 1974 and 1994, c) recent aerial imagery in 2021 (Nearmap), d) predicted vegetation changes from 1987 to 2020.

On the Central coast, the Karuah River (Figure 5), has experienced the greatest vegetation increase in the last 33 years (Figure 2). Unlike the Bega River, in the early 1980s, a considerable proportion of riparian zone in this section of Karuah River was already covered by vegetation (Figure 5-a). In the late 1990s, the vegetation coverage slightly expanded in both the riparian zone and in-channel zone (Figure 5-b). The vegetation change (Figure 5-c) shows a low level vegetation increase occurred in this river section, which is consistent with the transition from relative low vegetation to dense vegetation.

We could infer that the reason for the differences between the Bega and Karuah Rivers is the initial starting point of the analysis and the condition of the landscape at that time. We know that the level of vegetation clearance in the Bega was a lot higher than in the Karuah and so the modelled NDVI vegetation increase is relative to the initial stating point. This is a consideration we need to account for in our future work. Figure 3 shows that the vegetation increase was greater in the last 17 years than in the previous 16 years. Therefore, with more existing vegetation in the Karuah River, vegetation can increase more in extent but the intensity of the increase (e.g. NDVI difference) can be relatively low. Further work is required to explain these trends.

A section of the Bellinger River shows disconnected patches of vegetation in the riparian zone during the 1970s (Figure 6-a). In the 1990s, these vegetation patches progressively connected (Figure 6-b). Currently, vegetation covers the majority of the riparian and in-channel zones (Figure 6-c). Our prediction of vegetation changes also demonstrates this patchy vegetation increase shifts between low and high over time.

4.2 Limitations, future research and applications

NDVI is the most commonly used vegetation index to analyse vegetation changes (Adam et al., 2009, Gill et al., 2009). Previous studies have applied different NDVI thresholds to distinguish different levels of vegetation density depending on the region and vegetation type. Julien et al. (2011) classify a ground surface of NDVI ≥ 0.5, as high density vegetation, meanwhile Bertoldi et al. (2011) used 0.2 as the threshold to classify dense vegetation. Australian riparian vegetation generally has lower near infrared reflectance (i.e. lower NDVI) relative to deciduous, sclerophyllous vegetation with pendulous leaf form that needs to be accounted for in analyses. Additionally, the method is not yet trained to detect native vs exotic vegetation which we know is a key vegetation quality issue for returning vegetation in riparian systems in this region. NDVI is also limited in its capacity to distinguish grass/pasture from woody vegetation. The NDVI increase may well be influenced by pasture/grass growth rather than tree increase in the riparian zone. We need to consider other vegetation indices and characteristics (e.g. texture measure), and implement improved classification method (e.g. supervised classification using field collected reflectance data) to delineate the riparian vegetation recovery in our future work. We applied a uniform riparian buffer to analyse vegetation changes, which can lead to reduced accuracy for large rivers. Therefore, we also need develop a better delineation approach to account for different sized channels and valley bottom widths.

Once we are confident with our method and the output, we predict that the findings could be very useful to river management agencies and the community. The outputs could be used to determine where vegetation plantings are most required, to determine where weed management strategies need to take place, where monitoring and conservation needs to occur as well as use in a range of applied research projects.

5. Conclusions

We produced NDVI difference from Landsat imagery for the last 33 years to investigate the long-term vegetation change along the streamlines of all coastal river catchments in NSW. The results show that, for the entire region, 45% of stream length experienced a vegetation increase, and 52% of stream length remained the same but the riparian vegetation changes exhibit both temporal and spatial variation. The vegetation increase ranges from 32 to 61% of stream length in the 19 catchments. There was more vegetation increase in the last 17 years (2003 – 2020) than in the previous 16 years (1987 – 2003). Historical aerial imagery of river sections in the Bega River, Karuah River and Bellinger River confirmed the preliminary NDVI derived vegetation changes in extent and intensity.

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