

## Evaluation of Photo Imaging Methods for Vegetation Condition Assessment

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### ABSTRACT

The aim of this project was to assess the feasibility of a photo imaging approach in the assessment of vegetation condition attributes in comparison with the Queensland Department of Environment and Resource Management (QDERM) Vegetation Condition Assessment approach. The project applied both the QDERM *BioCondition* monitoring method and an alternative photo imaging analysis approach to the assessment of vegetation condition attributes on different regional ecosystems. The study focused on the comparability of results and the cost-effectiveness of the photo imaging approach in comparison to the standard *BioCondition* assessment method.

Six regional ecosystems (RE) sites, of varying structural complexity, were selected for this study. They contained a diverse range of different vegetation attributes. Each site was assessed using both approaches. A low-cost Canon *PowerShot SX10 IS* camera was used to collect the photographs. It is equipped with a 20x Optical Zoom lens with a focal length of 5.0-100mm that allows shooting a scene from wide-angle to telephoto. For the ground cover data collection, two vertical-down photographs were taken of each quadrat. To capture canopy cover, vertical-up photographs were taken at 5m intervals along the transect midline. A two pole photographic method was developed to estimate tree canopy height.

This study found that the use of photo imaging methods to measure most attributes of vegetation for the *BioCondition* approach is technically possible. However, their application for operational use in ecosystems with closed vegetation canopies is not feasible. The estimation of the vegetation condition variables is constrained, in various degrees, by several factors. The estimation of shrub species richness in grassland and open canopy forests are the only attributes that have potential for operational use. Canopy cover estimates from vertical-up photographs produced comparable *Tree Cover Rank* results compared to the manually based crown cover estimate method. The photographic technique also has good potential for estimating major classes of ground cover in quadrats. Canopy height can be estimated more easily by using a laser range finder than a photo imaging method. In the future, when the cost of data acquisition becomes less expensive, the suitability of a LiDAR system could be considered to quantify the desired vegetation attributes.

**KEYWORDS:** photo imaging, *BioCondition*, vegetation assessment, low-cost camera

## 1 INTRODUCTION

The loss, decline and fragmentation of habitat through excessive clearing of native vegetation poses a significant threat to native flora and fauna (e.g. Ford et al., 2009; Maron and Fitzsimons, 2007). This has been occurring in many parts of the world (e.g. in Southeast Asia, see review of Koh and Sodhi, 2010). In Queensland, Australia, the impacts of land clearing on native biota include reduced abundance, localised extinctions and declining viability of populations (Cogger et al., 2003). To abate this problem, conservationists and resource managers need to intensify habitat protection and recovery programs, in tandem with other conservation measures. In pursuing these programs, habitat areas need to be identified, mapped, and their condition assessed.

Habitat condition can be assessed at a range of spatial scales, i.e. from site to regional scales (Gibbons, et al., 2006). These include the following three approaches: on-ground site assessment, spatial modelling, and remote sensing. At a site scale, Gibbons and Freudenberger (2006) reviewed the different tools and techniques for rapid, on-ground assessments of vegetation condition and suggested a framework on developing new approaches. While on-ground assessment of vegetation condition has several uses, this approach is very time consuming and resource-intensive. It is therefore logical to develop innovative methods that can be used to reduce the volume of work and time required without compromising the completeness and accuracy of key information that site-based methods can provide.

In Queensland, the former Environmental Protection Agency (EPA) (now part of the Department of Environment and Resource Management) has conducted several studies to develop methods to survey, classify and map different vegetation communities. The *BioCondition* assessment technique was one of those vegetation condition methods developed for Queensland (Eyre et al., 2006). It provides a measure of how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values. This site-based method considers the structural, compositional and functional aspects of a vegetation community. As it depends on field-based site assessment of vegetation attributes, the amount of time and volume of work can be prohibitive when multiple sites need to be assessed.

The aim of this project was to assess the practicality, suitability, comparability and cost-efficiency of a photo (photographic) imaging approach in the assessment of habitat condition parameters in comparison with the DERM *BioCondition* (field survey) approach. This project applied both the *BioCondition* monitoring method and an alternative photo imaging analysis approach to the assessment of selected habitat condition parameters for a variety of regional ecosystems. The study focused on the comparability of results and the cost-effectiveness of the photo imaging approach in comparison to the standard *BioCondition* method. Six regional ecosystems (RE) sites (i.e. 11.3.21, 11.8.3, 11.8.15, 11.9.4a, 11.9.6, and 12.5.13) were included in this study.

## 2 USING TERRESTRIAL PHOTOGRAPHY IN BIOCONDITION ASSESSMENT

### 2.1 The *BioCondition* Approach

Information about the extent and condition of vegetation is necessary for integrated catchment management. Consequently, forest and vegetation assessment and monitoring programmes become integral to resource management efforts by government agencies and for environmental assessment purposes around the world (e.g. FAO, 2007). In Queensland, two major vegetation mapping programs exist: a) the Statewide Landcover and Trees Study (SLATS) and b) the Regional Ecosystems mapping program, both conducted by the Queensland Department of Environment and Resource Management. More recently, the former EPA developed the *BioCondition* framework for vegetation condition assessment.

The aim of the *BioCondition* assessment toolkit is to provide a framework that provides a measure of how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values compared to its undisturbed condition (Eyre et al., 2008; 2006). It is a site-based, quantitative and repeatable assessment procedure that provides a numeric score to each prescribed vegetation attribute. It considers the structural, compositional and functional aspects of a vegetation community.

The BioCondition methods are basically field-based, i.e. data should be collected at the field level. While on-ground assessments can be accurate at fine scales, they can be impractical for assessment across broad scales due to high expense of manpower, resources and time. Thus, it will be beneficial if other techniques can be developed to alleviate some of the key issues with the existing field-based approach. One of the potential techniques that can be used to assess BioCondition and reduce labour is terrestrial photography. Photographs can capture features of interest which can be analysed off-site, thereby providing opportunities to reduce time and effort during field work.

## 2.2 The Potential of Terrestrial Photography

Several studies have been done using ground based photographs taken using an ordinary digital/manual camera. For instance, the Department of Natural Resources and Water used photographic methods to keep visual records of land features to monitor short and long-term physical change at each location (NRW, 2006b). They have named it as "photopoints". Photopoints are permanent or semi permanent sites set up from where a series of photographs can be taken over time. For this purpose, the following ways of taking photographs were suggested:

- *Spot Photograph*: (near) vertical down photographs of specific locations from 1.6 m above the ground. This is for recording ground cover and species, and organic litter and bare soil.
- *Trayback Photograph*: taken standing on a vehicle tray back providing an elevation of approximately 3 metres. This is used primarily for assessing ground cover and condition.
- *Landscape Photograph*: they are used for showing shrub or tree layers, or the extent of events on the landscape such as floods or fire.

Images from photopoints can provide a valuable supporting record when monitoring the following (NRW, 2006b):

- Pasture condition, pasture species and yearly pasture use
- Ground cover, organic litter, shrub cover, recruitment of woody plants, tree canopy cover and health, and vegetation density
- Native vegetation area and wetland area
- Native plant richness, large trees, fallen woody material and in-stream habitat
- Impacts on native vegetation, impacts on wetlands
- Farm water flow, gully erosion, hill slope erosion and wind erosion
- Saline land and deep-rooted perennials
- Weed cover and weed species
- Effects of fire, drought, flood, dieback and feral animals
- Wind erosion

In a different application, Gilbert et al. (2009) used a digital camera to monitor *Calluna vulgaris* after a fire. The two trials undertaken, artificial and field-based, demonstrated the value of using digital photography as a tool in measuring vegetation cover. Comparing results from the digital and point quadrat methods indicated that they were not significantly different ( $P > 0.05$ ), permitting confident use of the digital technique. Enhanced speed of data collection was most useful in areas of poor climatic conditions or poor accessibility, such as on upland moors. Less time in the field reduces the effect of sampling fatigue on the results.

Time spent on computer analysis of images can be conveniently interrupted within a comfortable environment.

A study on grassland biomass estimation using ground based digital photographs was conducted in the U.S. (Vanamburg et al., 2005). The results showed that conventional (RGB) digital camera imagery was not useful on a shortgrass prairie for the estimation of aboveground biomass. The complex spectral characteristics of shortgrass prairie systems, especially as vegetation begins to senesce, limited the usefulness of this type of sensor for spectrally distinguishing among substrate components like soil, litter and brown vegetation. Detailed analysis of these data sets showed that shortgrass prairie ecosystems are spectrally very complex. Yet, as vegetation began to senesce throughout the season, these ecosystems exhibit a large amount of spectral overlap among substrate components. This caused considerable error between classes such as brown vegetation and soil, which increased classification error.

In another study, a technique for near ground remote sensing of herbaceous vegetation in tropical woodlands was developed (Northup et al., 1999). The procedures they applied were found efficient in the open eucalypt woodlands of northern Queensland. The technique was relatively cost-effective, and thought to be equally capable in ecosystems with open woody canopies, or in grasslands.

### **3 METHODS**

#### **3.1 Study Area**

The study area covered part of the Condamine Catchment (Figure 1). The catchment is located west of the Great Dividing Range in southern Queensland, covering an area of 24,434 km<sup>2</sup>. The area has a highly variable subtropical climate, with an average annual rainfall of 682-955mm, and average temperatures ranging from 3°C to 30°C (NRW, 2006a). The vegetation in the basalt hills is dominated by mountain coolibah, narrow-leaved ironbark and silver leaf ironbark. In soils associated with sandstone areas, patches of brigalow/belah, poplar box, ironbark, bullock and cypress pine are common. The extensive use of the area for agriculture and pasture has resulted in the loss of much of the original vegetation.

This study investigated six regional ecosystem (RE) types of varying structural complexity (Table 1). The vegetation communities include grassland, woodland, open forest, vine thicket and vine forest. These were selected to represent the range of assessable vegetation attributes in which the photo imaging method was to be tested. The grasslands (e.g. RE 11.3.21) were easier to assess than the vine thickets and vine forests (e.g. RE 11.8.3 and 12.5.13).

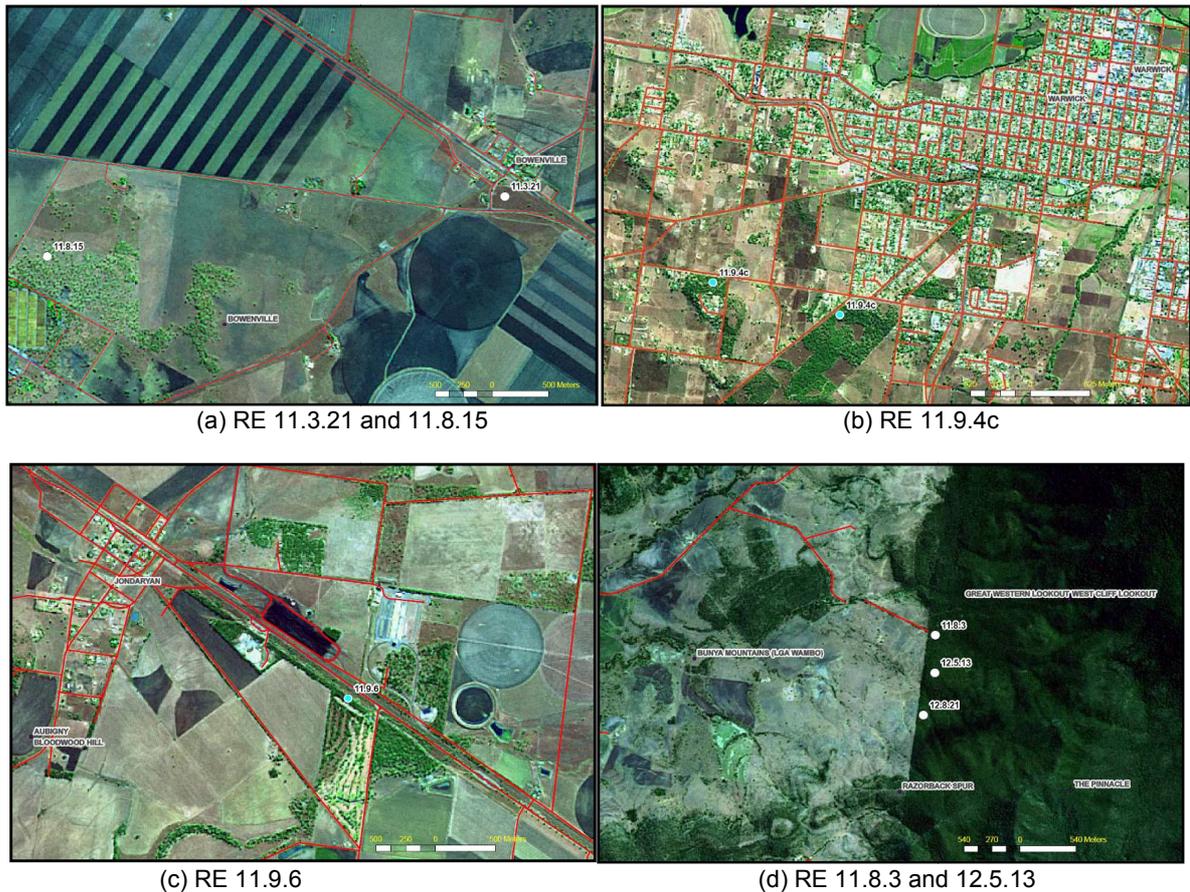


Figure 1: Location and image of the study area.

### 3.2 Field Data Acquisition

Sample data for assessment of the *BioCondition* of each Regional Ecosystem (RE) site (see Figure 1) were collected by similar methods to those outlined in the Queensland *BioCondition* Assessment Manual (BAM) (Eyre, et al., 2008). The methods were modified by the addition of increased photographic data collection as outlined in section 3.2.3 below.

#### 3.2.1. Transect Data Collection

The position of each 100 x 50 m transect for each RE was recorded using a Garmin Explorer GPS unit. Full Transect data were collected over the entire 100 x 50 m area of each transect. Sub-transect data were collected from a 50 x 10 m area in the centre of each transect. Large Tree measurements were based on up to 10 large trees selected at random (less if 10 trees were not present). Tree and Shrub canopy cover was assessed along the 100m centreline of all RE transects except for REs 11.8.3 and 12.5.3. Canopy cover was only collected along 50 m of centreline for these two REs. The thickness of the vegetation made it impractical to collect data along a 100 m centreline. Canopy cover (both tree and shrub) was recorded by vertical projection over the centreline. As such, it equates to crown cover (Walker and Hopkins (1990) as cited by Eyre et al., 2008). Canopy health scores were also collected according to the BAM procedures (p. 18). The height of the trees was measured using a "TruPulse™" 200 laser range finder.

Table 1 Regional ecosystems sampled in this study

Regional Ecosystems	Short Description	Structure Category	Location of Sample Sites
11.3.21	<i>Dichanthium sericeum</i> and/or <i>Astrelba spp.</i> grassland on alluvial plains. Cracking clay soils	grassland	Bowenville
11.8.15	<i>Eucalyptus brownii</i> or <i>Eucalyptus populnea</i> woodland on Cainozoic igneous rocks	sparse	Wainui
11.9.4a	Semi-evergreen vine thicket or <i>Acacia harpophylla</i> with a semi-evergreen vine thicket understorey on fine grained sedimentary rocks	dense	Warwick
11.9.6	<i>Acacia melvillei</i> +/- <i>A. harpophylla</i> open forest on fine-grained sedimentary rocks	mid-dense	Jondaryan
11.8.3	Semi-evergreen vine thicket on Cainozoic igneous rocks	dense	Bunya Mountain
12.5.13	Microphyll to notophyll vine forest +/- <i>Araucaria cunninghamii</i>	dense	Bunya Mountain

### 3.2.2. Ground Cover Data Collection

Ground cover data were collected from five 1m x 1m quadrats located at 10 m intervals along the transect centreline beginning at 25 m from the origin. At each quadrat (Figure 2), the percentage of vertical cover for each of 10 categories (Eyre et al. 2008) was estimated by averaging the estimates of two observers. Photographs of cover over each quadrat were taken in a standard manner (see Section 3.2.3 below). The manually collected data from 5 quadrats was averaged for each transect.



Figure 2: A 1m x 1m quadrat used in the field

### 3.2.3. Photographic Data Collection

From the literature review, brainstorming, and pre-testing of the methods, the team developed the following photographic data collection techniques:

- a) A 10 megapixel Canon *PowerShot SX10 IS* was used for this study (Figure 3). This camera features 10-megapixel resolution and new DIGIC 4 Image Processor for high-performance face and motion detection. It is equipped with a 20x Optical Zoom lens with a focal length of 5.0-100mm (35mm film equivalent: 28-560mm) that allows shooting a scene from wide-angle to telephoto. It cost approximately \$460 in 2009.



Figure 3: A 10 megapixel Canon *PowerShot SX10 IS*.

- b) For the ground cover data collection, two vertical photographs (with one as back up) were taken of each quadrat. A special set up was designed to make the photograph vertical (Figure 4).



Figure 4: Set up of the camera.

- c) For the canopy cover, a vertical upward photograph was taken at every 5m interval along the 100m transect to estimate the canopy cover from photographs.

- d) For the tree canopy height, two 2m graduated ranging poles were erected at the 25m and 50m points on the transect. A horizontal photograph of the site was taken from 10m away from the starting point of the transect. A similar record was made at the end of transect. These photographs were used to calculate the height of trees.
- e) Four photographs were taken in four 90 degree directions from midtransect to provide a reference record of the area.

### 3.3 Data Processing and Analysis

Manually collected data were analysed according to the Queensland *BioCondition* Assessment Manual (BAM) procedures (Eyre, et al., 2008). Different procedures were explored and tested for analysing the photographic data to evaluate the utility of inexpensive and readily available software. This study used *Pixcavator*, *Adobe Photoshop*, and *Adobe Acrobat Professional*.

#### 3.3.1. Transect Data Analysis

##### a) Manual Analysis

The full transect and sub transect values were recorded directly from the field. Large Tree data (for REs with large trees) were recorded for up to 10 specimens selected at random within the transect. The circumference at breast height (CBH at 1.3m) was recorded and used to calculate the diameter at breast height (DBH). This was averaged for each sample.

The canopy vertical intersect distances along the midline were converted to crown cover percentages. This was expressed as a percentage of the reference crown cover percentage for each RE (rel %) and used to identify the applicable row in Table 4 of the *BioCondition* Assessment Manual. The percent of crown health scores  $\geq 3$  was calculated and used to identify the applicable column in Table 4. The intersection of the Crown Cover percentage and the Crown Health percentage identifies the overall tree cover health of the ecosystem being investigated.

##### b) Photographic Data Analysis

To interpret the images taken in the field, the software *Pixcavator* was used. This software allowed us to choose a channel and classify the image using an object-based approach. To determine the percentage cover of the canopy, the blue channel was selected to process the photograph. The blue channel was found suitable for canopy cover estimation as it has a low response to vegetation components and hence gives more dark pixels during classification. After the application of the edge enhancement (“dilation”) filter, the image was classified. Generally the software divides the whole image into dark and light classes, i.e. a group of patches of bright or dark pixels in the image based on given threshold values). From this, the percentage of canopy cover can be estimated.

The classification output resulted in three general possibilities (Figure 5):

- a. All canopy cover was classified as dark class and blue sky (not the open sky) seen through the canopy as light class. In this case,  
Canopy cover = dark class – light class
- b. In the case where most of the photograph was covered by canopy, then only the holes of blue sky were classified as light class, in this case,  
Canopy cover = 100 – light class
- c. Only the canopy cover was classified as dark class, in this case,  
Canopy cover = dark class

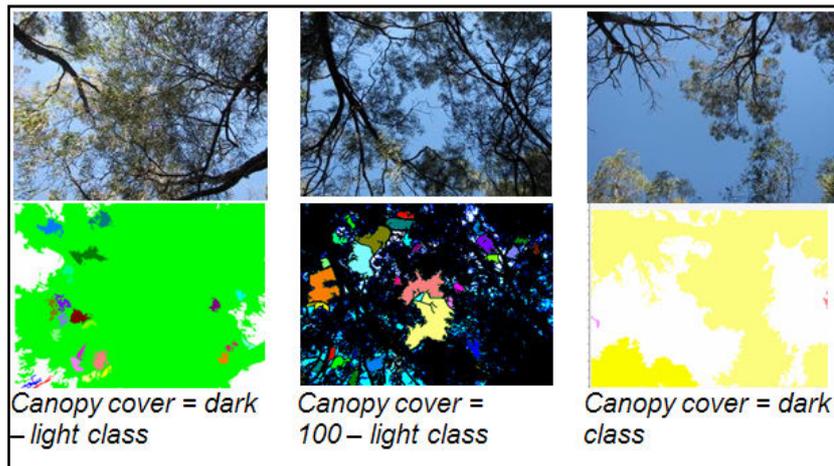


Figure 5: Three potential classification results for canopy cover calculation in *Pixcavator*

2. The average of the canopy cover values was calculated and compared to the result from the manual method.

### **3.3.2. Ground Cover Data Analysis**

Ground cover was estimated in three different ways: manual field estimation, photographic estimation and gridded photographic estimation. Other methods such as pixel classification with Adobe Photoshop software and object classification with Pixcavator software were explored but yielded impractical results. Pixcavator was not found to be a good software to classify different types of ground cover features due to the limited capacity of the software to create multiple classes. Human knowledge of vegetation and cover types (by their texture, pattern and shape) and the colour of features were found more important to analyse the photograph.

#### **a) Manual Field Estimation**

Two observers inspected each of the 5 quadrats in each transect and agreed on the percent of each cover type. The figures for each transect were averaged and then grouped into the three *BioCondition* ground cover categories: perennial grasses, perennial non grasses and annual species as well as organic litter cover. The values were compared with reference ecosystem values for each RE.

#### **b) Photographic Estimation**

A standard photograph of quadrat 3 from each transect was displayed on a nominal 24" LCD screen using Adobe Acrobat 6.0 software. An informed observer visually estimated the percent of each type of ground cover.

#### **c) Grid Photographic Estimation**

A standard nominal grid (1 cm cell size) was displayed over the same photograph using Adobe Acrobat 6.0 (Figure 6). Seven cover class stamps were created and each grid cell was stamped according to the type of majority cover in the cell. The percent of each ground type cover was calculated by summing each class stamp and expressing it as a percentage.



Figure 6: Grid photographic estimation method of ground cover

### 3.4 Assessment of the Methods Used

As indicated before, the aim of this project was to assess the practicality, suitability, comparability and cost-efficiency of photo imaging approach in the assessment of habitat condition parameters with reference to the *BioCondition* approach. In this regard, we assume the following:

- The photo imaging method should be as simple as possible, i.e. the sensor is a low-cost (<\$500), “off-the-shelf” camera system. This cost limitation precludes the use of a multi-spectral band (e.g. near infrared channel) camera.
- The software system used in digital analysis of the photographs should be inexpensive (<\$500) and relatively easy-to-use, i.e. without the need to perform complex image processing tasks.
- The analyst user of the system does not need to be an expert in image processing, but only to have a basic knowledge of graphics and digital data handling.

In the assessment of the potential photo imaging methods, this study considered two main criteria:

- technical possibility – this refers to the prospect that a parameter (e.g. canopy height) can be measured using the photo imaging method regardless of the resources (time, labour, supporting equipment, etc.)
- operational feasibility – this refers to the prospect that a parameter (e.g. canopy height) can be measured using the photo imaging method within the confine of set resources or costs. A method was considered not operationally feasible if the cost (labour, software, hardware, user training, time, etc.) of implementing it was equal to or greater than the standard *BioCondition* method.

## 4 RESULTS

### 4.1 Estimating Transect and Sub-transect Attributes

Table 2 shows the manually collected field attribute measurements for each of the six RE sample sites and the investigating team's evaluation of the technical and operational feasibility of collecting similar information from extensive site photographs. These results show that in grassland and open woodland (savannah) ecosystems (REs 11.3.21, 11.8.15 and 11.9.4c), it is technically possible to extract each attribute with a medium level of difficulty. However it is not operationally feasible because it would take too much time and software skill to do it. Estimation of the canopy height of trees was an exception to this finding in that it was very possible (high rating) to calculate these accurately from photographs. However, because of the time and skill required, it was judged as operationally unfeasible.

Table 2 Estimates of the Feasibility of Measuring Transect and Sub-Transect Attributes from Photographs compared to Field Measurements.

RE category	Measurement Type	Full Transect					Sub Transect							
		Lge Tree spp #	Recruit %	Lge tree c hol	DBH (cm)	Canopy height (m)	Shrub spp #	Grass spp #	Herb + Forb spp	Other spp #	Weed cvr %	Fallen logs #	Fall logs decay %	
RE 11.3.21 (Bowenville)	Field Measurement	No trees in this regional ecosystem transect sample*					0	2	5	1	0	No trees in this regional ecosystem sample*		
	Reference Value						0	7	11	4	0			
	Photo Meas.(Tech Possible)						Med	Med	Med	Med	Med			
	Photo Meas. (Oper Feasible)						Yes	No	No	No	No			
RE 11.8.15 (Wainui)	Field Measurement	1	100	13	62.39	10.32	1	2	5	1	1	2	13	
	Reference Value	1	-	-	54	22	5	6	13	2	0	40	-	
	Photo Meas.(Tech Possible)	Med	Med	Med	Med	High	Med	Med	Med	Med	Med	Med	Med	
	Photo Meas. (Oper Feasible)	No	No	No	No	No	Yes	No	No	No	No	No	No	
RE 11.9.4c (Warwick)	Field Measurement	1	5	2	38.52	7.94	2	5	2	0	5	8	0	
	Reference Value	4	-	-	38	16	8	8	5	5	0	6	-	
	Photo Meas.(Tech Possible)	Med	Med	Med	Med	High	Med	Med	Med	Med	Med	Med	Med	
	Photo Meas. (Oper Feasible)	No	No	No	No	No	No	No	No	No	No	No	No	
RE 11.9.6 (Jondaryan)	Field Measurement	5	100	12	34.03	6.96	1	2	4	0	1	>10	>10	
	Reference Value	3	-	-	17.3	15	4	8	6	4	0	3	-	
	Photo Meas.(Tech Possible)	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	
	Photo Meas. (Oper Feasible)	No	No	No	No	No	No	No	No	No	No	No	No	
RE 11.8.3 (Bunya 1)	Field Measurement	4	100	1	68.44	5.21	5	1	2	2	20	10	50	
	Reference Value	12	-	-	22	7	17	2	3	15	0	9	-	
	Photo Meas.(Tech Possible)	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	
	Photo Meas. (Oper Feasible)	No	No	No	No	No	No	No	No	No	No	No	No	
RE 12.5.13 (Bunya 2)	Field Measurement	4	100	4	37.24	4.92	4	1	4	1	20	30	55	
	Reference Value	19	-	-	32	23	23	1	4	13	0	23	-	
	Photo Meas.(Tech Possible)	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	
	Photo Meas. (Oper Feasible)	No	No	No	No	No	No	No	No	No	No	No	No	

Med = Medium difficulty

\* The assessment from photos would be technically and operationally feasible if a few scattered trees occurred in what was otherwise open grassland.

In closed woodland ecosystems (REs 11.9.6, 11.8.3 and 12.5.13), there was a low level of technical possibility of extracting the attribute information accurately and it is not operationally feasible to extract such information.

The photogrammetric method yielded the same Tree Cover Rank as the manual method for all REs (Table 3). This occurred despite substantial differences between the canopy cover percentages derived from the vertical-up photographs and the crown cover percentages recorded along the transect midline (see column 4). The relative cover percentages (measured relative to RE reference values) all fell within category 3 in Table 4 of the BAM. The Health Scores and Relative Health Scores from the photographs were similar to the field recorded values. This resulted in all REs having less than 30% of their canopies with a Health Score greater than 3.

Table 3 Estimates of Canopy Cover Attributes for Five Sample Regional Ecosystems

RE category	Method	Value Type	Crown Cover %	Health Score (%≥3)	Tree Cover Rank <sup>1</sup>
RE 11.3.21 (Bowenville)	Existing method	Measured	No trees in this regional ecosystem transect sample		
		Relative			
	Reference value				
	Pixcavator method	Measured			
Relative					
RE 11.8.15 (Wainui)	Existing method	Measured	54		4
		Relative	130.1	31	
	Reference value		41.5		
	Pixcavator method	Measured	27.15		4
Relative		65.4	33		
RE 11.9.4c (Warwick)	Existing method	Measured	66.5		5
		Relative	99.3	14	
	Reference value		67		
	Pixcavator method	Measured	40.4		3
Relative		60.3	11		
RE 11.9.6 (Jondaryan)	Existing method	Measured	84.8		5
		Relative	101	0	
	Reference value		84		
	Pixcavator method	Measured	83.97		5
Relative		100.0	0		
RE 11.8.3 (Bunya 1)	Existing method	Measured	61		5
		Relative	64	7	
	Reference value		95		
	Pixcavator method	Measured	64.19		5
Relative		67.6	20		
RE 12.5.13 (Bunya 2)	Existing method	Measured	74		5
		Relative	82	0	
	Reference value		90		
	Pixcavator method	Measured	81.18		5
Relative		90.2	0		

1. Derived from Table 4 of the BioCondition Assessment Manual

The average of the canopy cover values calculated from photographs was compared to the result of the manual method. For REs 11.9.6, 11.8.3, and 12.5.13, the values calculated from the photographs and the manual method were relatively close, i.e. 83% vs. 84%, 64% vs. 61%, and 81% vs. 74%, respectively. In these cases, it suggests that the photo imaging method is capable of producing comparatively accurate results. However, for RE 11.8.15, there is a large difference between the values: 27% vs. 54%.

#### 4.2 Estimating Ground Cover Attributes

Table 4 provides illustrative results of two photographic methods (Photo and Gridded Photo) and the Field Method for measuring the percentage of four categories (BAM categories) of ground cover in 1m<sup>2</sup> quadrats sampled at the 45 m interval along the midline of each transect. The results indicate that it is difficult to make generalisations about the accuracy of the photo imaging methods. The percent deviation (or relative error) ranges from as low as 6% (perennial non-grass for RE 12.5.13) to a very high 167% (annual species for

RE 11.9.4c). In general, the grassland RE 11.3.21 exhibited the lowest relative error of estimation.

Table 4 Estimates and Percent Deviation (Relative Error) of Ground Cover Attributes by Three Different Methods

RE Category	Estimate Method	Ground Cover Type (Center Quadrat/Transect only)			
		Perennial grass	Perennial non-grass	Annual species	Organic Litter
RE 11.3.21 (Bowenville)	Field Estimate	45	25	0	25
	Photo Estimate	58	20	0	20
	Gridded Estimate	82	14	0	20
	Reference Value <sup>1</sup>	51	1.6	0	42
	% Dev Photo Estimate	29	-20		-20
	% Dev Gridded Estimate	82	-44		-20
RE 11.8.15 (Wainui)	Field Estimate	64	3	0	12
	Photo Estimate	80	0	0	5
	Gridded Estimate	87	0	0	8
	Reference Value	26.5	12	0	45
	% Dev Photo Estimate	25	-100		-58
	% Dev Gridded Estimate	36	-100		-33
RE 11.9.4c (Warwick)	Field Estimate	0	0	24	75
	Photo Estimate	0	0	50	50
	Gridded Estimate	0	0	64	36
	Reference Value	5.3	1	2	66
	% Dev Photo Estimate			108	-33
	% Dev Gridded Estimate			167	-52
RE 11.9.6 (Jondaryan)	Field Estimate	30	18	0	44
	Photo Estimate	7	15	0	73
	Gridded Estimate	21	7	0	69
	Reference Value	15	5.4	0	74
	% Dev Photo Estimate	-77	-17		66
	% Dev Gridded Estimate	-30	-61		57
RE 11.8.3 (Bunya 1)	Field Estimate	3	5	0	30
	Photo Estimate	0	0	0	60
	Gridded Estimate	0	0	0	34
	Reference Value	4.6	0.8	0	50
	% Dev Photo Estimate	-100	-100		100
	% Dev Gridded Estimate	-100	-100		13
RE 12.5.13 (Bunya 2)	Field Estimate	0	80	0	15
	Photo Estimate	0	85	0	5
	Gridded Estimate	0	85	0	12
	Reference Value	0	0.7	0	87
	% Dev Photo Estimate		6		-67
	% Dev Gridded Estimate		6		-20

<sup>1</sup>Reference Values taken from the RE Fact Sheets (2007) published by QDERM (2010).

## 5 DISCUSSION

### 5.1 Estimating Transect and Sub-transect Attributes

This study found that while the majority of vegetation condition attributes can be estimated technically from photo imaging methods (particularly for grassland and open woodland ecosystems), their application for operational use in densely vegetated ecosystems is limited or not feasible. The following constraints were identified from this research:

- a) **Tree canopy cover and native shrub cover:** Despite the very high agreement between the manual method and photo imaging method in estimating the Tree Cover Rank (related to crown cover and health score), the photo imaging method is not feasible for operational use in densely vegetated areas. This is because (i) collecting vertical-upward photographs in dense vegetation was very time consuming due to the difficulty in moving the camera rig and its set up, and (ii) the analysis of photographs and calculations of the percent crown cover took a long time, even with experienced analysts.

- b) **Large trees:** as this involved counting the number of large (as identified by a DBH threshold) living trees per hectare within 100 x 50 m assessment area, it was not practical to take photos of the entire plot in densely vegetated areas to selectively count the large trees. In contrast, the assessment from photos would be technically and operationally feasible where a few scattered trees or shrubs occurred in what was otherwise open grassland.
- c) **Tree canopy height:** technically, it was possible to accurately estimate this parameter from photo imaging method as shown in this study. However, for densely vegetated areas, this method became impractical for routine operational use. One key reason was the difficulty in seeing the measuring poles in a perspective where the top of the canopy was captured from a distance. Understorey growth prevented the measuring poles to become visible on the photos, thus calculation did not become feasible. It was demonstrated in this study that the use of a laser range finder (e.g. “TruPulse™” 200) is more suitable for measurement of tree height than the photo imaging method. The cost of such equipment ranged from \$800-\$1,500 in 2009.
- d) **Native plant richness by lifeform group:** with the *Biocondition* method, assessment involves counting the number of native species observed in the 50 x 10 m plot, for five life-forms: trees, shrubs, grasses, forbs and others. Using the photo imaging method for densely vegetated area, the technical possibility is relatively low due to the dual need of photographing vegetation comprehensively (i.e. covering the required areal extent) and the botanical or dendrological skill needed to identify different plant species. However, for grasslands and sparse forests, the photo imaging method has operational use for determining shrub species richness, as they “stand out” from the grass matrix.
- e) **Fallen woody material:** As it involved counting the number of fallen woody logs and other debris found within the 50 x 10 m plot, it is not operationally feasible to use photo imaging methods for this purpose in densely vegetated areas. Even for grassland and open forest areas, locating and counting the number of fallen woody materials from photographs was difficult because grasses and forbs covered some of the material.

## 5.2 Estimating Ground Cover Attributes

In estimating organic litter and ground cover (native grasses and others) using the photographic method, grassland RE 11.3.21 produced the lowest relative error of estimation. In some REs, the accuracy of ground cover estimates is relatively high. However, the results of this study are inconclusive for regional ecosystems with dense vegetation. The range of percent deviation is large, i.e. 6% to 167%. In hindsight, it may be possible that the field estimates, considered as the “acceptable” true value, may not be the case, as they are also prone to human estimation error. It may be that the photographic method provided a more objective method. This would need further investigation. Nevertheless, this study showed that the photographic technique has a good potential for operational use in estimating organic litter and ground cover.

It appears that the two photo analysis methods (i.e. using the photographic canopy estimation method and the ground cover photographic estimation) yield results that are generally close to each other. Thus, it seems that the added time it takes to do the grid analysis procedure is not warranted. The net effect is that the manual estimate from the photos could then be done using any freely available image viewer, such as Microsoft Office Picture Manager.

### 5.3 Other Relevant Issues

The *Biocondition* Assessment Manual describes a procedure for measuring “canopy cover”. It consists of expressing the vertical projection of the canopy as a percentage of the midline of a selected transect. The authors of that report acknowledge that they are using the term “canopy cover” synonymously with the term “crown cover”.

In this project, vertical-up photographs taken every 5 m along the transect midline were analysed in a software (Pixcavator) that identified areas of canopies that contained a majority of leaves. For most canopies, this was less than the area which encompassed the “crown cover” of the tree. The consequence of this is that for a given tree crown of 100%, the canopy cover was well less than 100%. As a consequence, the transect canopy percentages measured by Pixcavator, from 10 vertical-up photographs along the transect midline, may be expected to be less than the comparable percentage crown cover measurement and less than the referenced amount. This may warrant a new reference value for “canopy cover” percentage as distinct from “crown cover” percentage.

The existing BAM is based on on-site physical measurement of Regional Ecosystem attributes. On-site assessment is very time consuming and labour intensive. Application of new and existing technologies may offer the potential for more rapid assessment of vegetation condition. Such technologies include ground based stereo imagery, NIR imagery and LiDAR scans, large scale aerial stereo photographs and new high resolution satellite imagery such as DigiGlobe II. The new technologies offer the opportunity to collect data about current and new attributes. It would seem appropriate to investigate the range of such new attributes that might be collected by using these emerging technologies, as well as their cost effectiveness, their relationship to the existing benchmark attributes and values, and the possible development of new RE reference values specific to these technologies.

## 6 CONCLUSION

This study found that the use of photo imaging methods to measure most attributes of vegetation under the BioCondition approach is technically possible. However, their application for operational use in ecosystems with closed vegetation canopies is not feasible. The estimation of the vegetation condition variables is constrained, in various degrees by, a) the difficulty in setting up and operating the camera system and related equipment in thick vegetation, b) the inexpensive, “off-the-shelf” RGB camera (vs. multi-spectral NIR-equipped) system is limited in its ability to discriminate photosynthetic and non-photosynthetic vegetation features, and c) the low-cost software system does not provide sufficient functionality to conduct the desired image discrimination tasks.

For the parameters considered in this study, the estimation of shrub species richness in grassland and open canopy forests are the only attributes that have potential for operational use. Canopy cover estimates from vertical-up photographs produced comparable Tree Cover Rank results compared to the manually based crown cover estimate method. The photographic technique also has good potential for estimating major classes of ground cover in quadrats. Canopy height can be estimated more easily by using a laser range finder than a photo imaging method. This study recommends that for the estimation of quadrat-based variables, i.e. for ground cover and litter, the use of an NIR camera be tested. These cameras have more ability to discriminate between photosynthetic and non-photosynthetic vegetation and soil. In the future, when the cost of LiDAR data acquisition becomes more economical, it should be considered for landscape scanning (horizontal application) for tree size and density and for canopy height and health.

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