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RESEARCH ARTICLE

Determining an appropriate minimum mapping unit in vegetation mapping for ecosystem restoration: a case study from the Everglades, USA

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Abstract This paper documents the analyses that were conducted with regards to investigating an appropriate Minimum Mapping Unit (MMU) to be used to capture the potential changes in vegetation patterns for a 10,924 square km restoration project being conducted in south Florida, USA. Spatial landscape and class metrics that were shown to change predictably with increasing grain size were adopted from previous studies and applied to a multi-scale analysis. Specifically, this study examines the effects of changing grain size on landscape metrics, utilizing empirical data from a real landscape encompassing 234,913 ha of south Florida's Everglades. The objective was to identify critical thresholds within landscape metrics, which can be used to provide insight in determining an appropriate MMU for vegetation mapping. Results from this study demonstrate that vegetation heterogeneity will exhibit dissimilar patterns when investigating the loss of information within landscape and class metrics, as grain size is increased. These results also support previous findings that suggest that landscape metric "scalograms" (the response curves of landscape metrics to changing grain size), are more likely to be successful for linking landscape pattern to ecological processes as both pattern and process in ecological systems often operate on multiple scales. This study also incorporates an economic cost for various grain dependant vegetation mapping scales. A final selection of the 50 × 50 m grain size for mapping vegetation was based on this study's investigation of the "scalograms", the costs, and a composite best professional judgment of seasoned scientists having extensive experience within these ecosystems.

Keywords Minimum mapping unit · Scalograms · Thresholds

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Introduction

The Comprehensive Everglades Restoration Plan (CERP-www.evergladesplan.org), authorized as part of the Water Resources and Development Act (WRDA) of 2000 (US Congress 2000), is an $11 billion hydrologic restoration project aimed at providing benefits to all of south Florida. CERP includes 68 separate projects to be managed over the next 30 years by the South Florida Water Management District (SFWMD), the US Army Corps of Engineers (USACE), and other State and Federal agencies. Restoration Coordination and Verification (RECOVER) is a system-wide program within the CERP, designed to organize and provide the highest quality scientific and technical support during implementation of the restoration program (RECOVER 2004a). It is the role of

RECOVER to develop a system-wide Monitoring and Assessment Plan (MAP) (RECOVER 2004b) that will document how well the CERP is meeting its objectives for ecosystem restoration. One component of the MAP is to document changes in the spatial extent, pattern, and proportion of plant communities within the landscape.

A series of meetings among Federal, State, and Local agencies having a vested interest in the outcome of this project, were conducted to decide upon methodologies for mapping and classifying vegetation within the CERP boundary (Fig. 1). Those meetings resulted in the decision to utilize 1:24,000 scale color-infrared aerial photography data to create the first vegetation base map for the project. Stereoscopic photo-interpretation utilizing analytical stereoplotters and softcopy workstations would be implemented. A hierarchal classification system (Rutchey et al. 2006) was developed that was specific to the South Florida natural areas where this mapping was to be conducted. Another important and debated consideration was whether to use a vector or grid based system for mapping. Considering the spatial extent of the project it was decided that a grid system would be more suitable for a number of reasons. The first consideration was for economy as it was believed that a cost savings of thirty to fifty percent could be obtained using a grid system for mapping. Also, a grid system was more computationally efficient and better suited to evaluation using map algebra and complex spatial analysis (e.g. change detection). A spatially fixed grid can be overlaid on any spatially appropriate aerial photography, which enables the vegetation to be classified at the exact grid locations through time. Discussion then focused on determining the spatial grain or Minimum Mapping Unit (MMU) that would be utilized to map the vegetation communities. This would influence not only how well a map captures the spatial heterogeneity of the ecosystem, but also whether there is enough detail to capture significant changes through time. This topic was debated at length, with field ecologists typically arguing for a smaller MMU (on the order of 2 × 2 to 20 × 20 m) and ecologic and hydrologic modelers at the other extreme, wanting coarser MMUs (ranging from 500 × 500 to 1,000 × 1,000 m).

The optimum MMU should provide as much information as possible at a minimum economic cost, without losing necessary spatial information and provide the desired precision for enabling change detection through the mapping of the vegetation cover (Xiangyun et al. 2005). Since costs often constrain a mapping program, researchers typically will reduce the number of vegetation categories considered and/or increase the MMU (Stohlgren et al. 1997). Hence, both precision and cost are factors that can have an effect on the final selection of the MMU, but ideally the optimum MMU falls within the constraints of the economics. This paper documents the analyses that were performed to determine an appropriate MMU that would be used to capture the potential changes in vegetation patterns for this historic restoration project. Specifically, the study examines the effects of changing grain size on landscape metrics, utilizing empirical data from a real landscape.

Reference to "scale" or "characteristic scale" in this work refers to the intrinsic and distinctive scale that applies to the spatial or temporal dimension of a specific phenomenon under study (e.g. ecological patterns). "Scale effects" or "changing scale" refers to the alteration in the result with regards to the phenomenon under study due to changing the grain size under which it is observed (Wu and Li 2006). Scale effects on landscape metrics have increasingly been studied in recent years (Turner et al. 1989; Cullinan and Thomas 1992; Costanza and Maxwell 1994; Benson and MacKenzie 1995; Qi and Wu 1996; Obeysekera and Rutchey 1997; Stohlgren et al. 1997; Hay et al. 2001; Saura 2002). These studies have made ecologists acutely aware that changing scale often affects landscape metrics. However, many of these studies lacked an in-depth analysis at how these landscape metrics were affected by changing scale in classifying real landscapes. Quantification problems resulting from arbitrarily selecting a MMU or grain size are commonly described as the modifiable area unit problem or MAUP (Openshaw 1984). Randomly selecting a MMU either by choice or by utilizing available remote sensing data will produce results that may not necessarily represent the true heterogeneity of the ecosystem that you are mapping. Wu and Li (2006) state that most natural phenomena have distinctive scales that characterize their behavior or formation and identifying these characteristic scales can lead to profound understanding of the phenomena being studied. Thus, understanding how changing grain size affects landscape metrics (e.g., how patterns change

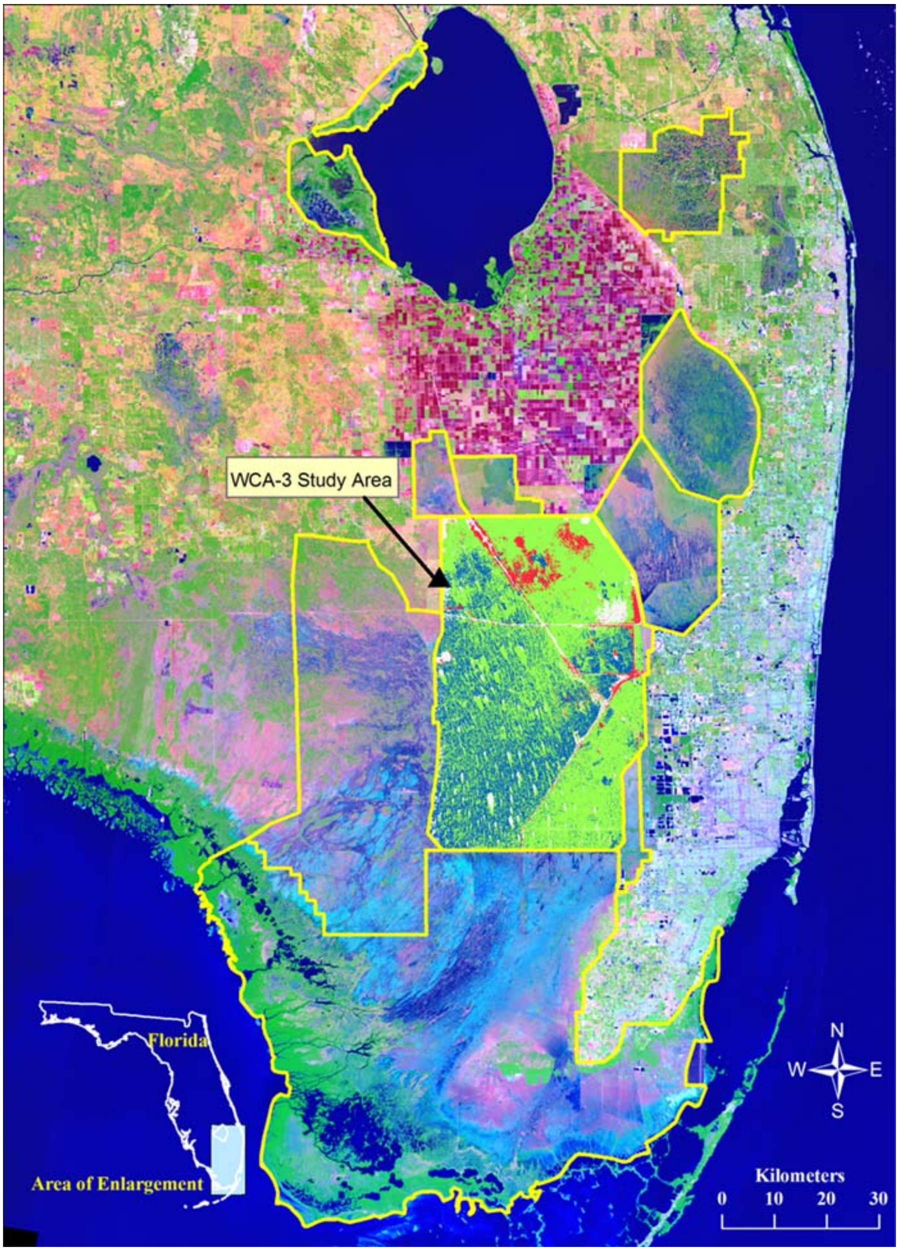

Fig. 1 Color infrared Landsat image showing the CERP boundaries in *yellow* with WCA-3 colorized vector map overlaid to show study area. Note: *Colors* in overlaid WCA-3 map represent: *Green* = Sawgrass; *Blue* = Wet Prairies; *Red* = Cattail; and *White* = Other

with scale) may provide a framework for spatially defining critical landscape scale thresholds. Can landscape metrics be utilized to investigate scale changes that have an ecological threshold?

Wu et al. (2002, 2004) systematically examined how pattern indices (measured by 19 landscape-level metrics and 17 class-level metrics) changed with scale (changing grain size). Their emphasis was on finding relations for certain landscape and class level metrics that were consistent across several different landscapes in North America. Twelve of the nineteen landscape metrics and five of the seventeen class metrics changed predictably with increasing grain size, exhibiting simple scale effect relationships that were robust across the different landscapes that were analyzed. These studies provide a subset of predictable landscape metrics that are being applied here in a scale effect analysis that investigates a detailed Everglades map. The objective of the study is to determine if there are critical landscape thresholds, which can be used to provide insight in determining an appropriate MMU for the CERP RECOVER vegetation mapping project.

Methods

An existing vegetation map of Water Conservation Area 3 (WCA3), the creation of which relied upon manual stereoscopic analysis of high resolution 1994/1995 1:24,000 scale color infrared positive aerial photo transparencies (23 × 23 cm format), was utilized in this current study (Fig. 1) (Rutchey et al. 2005). A Leica SD2000 analytical stereoplotter with a resolving resolution of three microns (equal to less than one foot on the aerial photography) was utilized for the vegetation class identification. The scheme used to delineate the WCA3 vegetation was the Classification System for South Florida National Parks (Jones et al. 1999). Up to three codes of vegetation classes, representing the dominant, co-dominant, and third dominant, could be included to label any delineated polygon. Twenty-four hundred and two ground truthing sites, selected from the aerial photos where photo signatures were questioned or unrecognized, were visited in the field by helicopter or airboat, utilizing real-time Global Positioning System (GPS) navigation. These field verification data were then utilized in the mapping process. Two hundred and four random sampling points were utilized for an overall map accuracy assessment. Binomial probability formulas require the use of a minimum of 204 points to check for an 85% accuracy level with an error of ±5% (Snedecor and Cochran 1978). The overall map accuracy was 89.7% when dominant, co-dominant, and third dominant classifications were considered; 90.7 when only dominant and co-dominant were considered; and 93.1 when only the dominant vegetation was considered. This dataset is believed to be one of the most detailed, spatially explicit, vegetation record, over such a large extent (234,913 ha), ever compiled for any part of the Everglades and is being used extensively as a vegetation class base map in the CERP RECOVER restoration process. The compiled vegetation map cover included a total of 155,434 photointerpreted polygons, of which the largest group of polygons (52,683 or 33.9%; Fig. 2) were 0.01 to 0.05 ha in size. The area is dominated by sawgrass (Cladium *jamaicense)* (60%) and wet prairie communities (27.4%). This type of community dominance is characteristic of the freshwater Everglades. The remaining 12.6% cover consisted of cattail (Typha spp.), tree/shrub species, broadleaf marshes, cypress, exotics such as Melaleuca spp., and areas of human influence (e.g. spoil areas and artificial deer islands). The final ArcInfo polygon, vector topology coverage product was in the Universal Transverse Mercator (UTM) coordinate system referenced to the North American Datum of 1983 (NAD 83).

For this analysis, ArcInfo raster based Grids were each created from the original WCA3 ArcInfo vegetation coverage file. Re-sampling was performed to produce Grids which resulted in data files having the same extent but with different grid sizes of 10 × 10, 16 × 16, 20 × 20, 25 × 25, 40 × 40, 50 × 50, 60 × 60, 70 × 70, 80 × 80, 90 × 90, 100 × 100, 125 × 125, 150 × 150, and 175 × 175 m (Fig. 3). The original WCA3 ArcInfo coverage dataset was utilized for each aggregation using a majority rule. Grids that fell on the edge of the coverage were treated in the same majority rule manner with no-data cells counting in the majority rule decision. This resulted in commission and omission of grid cells along the edges,

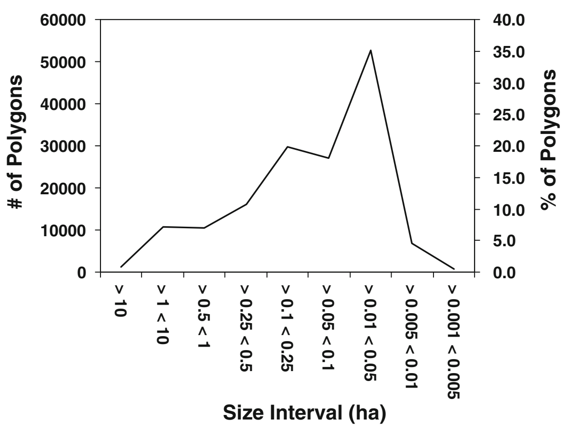

Fig. 2 Distribution of polygons within size intervals for the Water Conservation Area 3 Vegetation Mapping Project (total number of delineated polygons = 155,434)

which subsequently did not produce any problematic artifacts due to the overall large extent of the project area (234,913 ha). For each of the re-sampled ArcInfo Grid datasets, we utilized Fragstats 3.3 (McGarigal and Marks 1995) to calculate landscape and class metrics that Wu et al. (2002, 2004) found to exhibit simple scaling relationships that were robust and changed predictably with increasing grain size (Table 1). The landscape metrics calculated were: Number of Patches (NP), Total Edge (TE), Patch Density (PD), Edge Density (ED), Landscape Shape Index (LSI), Area Weighted Mean Shape Index (AWMSI), Area Weighted Mean Fractal Dimension (AWMFD), Patch Size Coefficient of Variation (PSCV), Mean Patch Size (MPS), Square Pixel (SqP), Patch Size Standard Deviation (PSSD), and Largest Patch Index (LPI). Class metrics for sawgrass, wet prairie and cattail (these comprised 92.5% coverage of the area) were calculated for NP, TE, PD, ED, and LSI. All Fragstats output data were imported into Microsoft Excel spreadsheets. Scalogram plots for each of the landscape and class metrics were created to show changes to each of the spatial metrics utilized as grain size was increased from 10 × 10 to 175 × 175 m.

The current CERP RECOVER vegetation map, at a 50 × 50 m grid resolution, costs ~\$560.00 per hectare to produce. The costs for compiling these 50 × 50 m grid vegetation map products were extrapolated for the other grid resolutions utilized in the current study and a graph produced within Microsoft Excel spreadsheets.

Results

Figures 4 and 5 are plots (scalograms) of how the landscape and class metrics responded to changes in increasing grain size. These results are similar to the findings of Wu et al. (2002, 2004) for landscape and class metrics when changing the grain size. Nine of the landscape and all five of the class metrics decreased in value with increasing grain size, with three of the landscape metrics showing an increase with increasing grain size (Figs. 4, 5). This study also found that NP and PD exhibited identical correlating relationships for both class and landscape metrics. Total Edge (TE), ED, and LSI for landscape and TE and ED for class metrics also exhibited an identical scale effect relationship. The output data for the AWMSI and AWMFD metrics were also highly correlated ($r = 0.96$).

Notable observations within the graphics (Figs. 4, 5) include the MPS and PSSD line slopes, which appear to change between grid sizes of 50 × 50 to 60 × 60 and 30 × 30 to 40 × 40, respectively. Cullinan and Thomas (1992) noted that interpreting MPS is difficult and that one cannot assume that the MPS is an appropriate level of resolution for a study of landscape dynamics without confirmation from other metrics. They stressed that a single spatial indice should not be relied upon to provide the correct interpretation because each metric addresses a different statistical question and will display different sensitivities with changing scale. Number of Patches (NP) decreased from 119,529 to 2,575 for the 10 × 10 to 175 × 175 grids sizes, respectively. Saura (2002) found that in relation to configuration that the NP and MPS are very sensitive to changes in grain size and are considered very poor indicators of landscape fragmentation. The Largest Patch Index (LPI), which represents the percentage of total landscape area comprised by the largest patch, changed abruptly from 15.4 to 20.4% for the 40 × 40 to 50 × 50 grid sizes and again from 21.4 to 39.6% for grid sizes of 150 × 150 to 175 × 175. Forman (1995) reported that the size of the LPI may limit or affect many ecological phenomena, an important consideration when evaluating change, particularly due to fragmentation. The AWMSI, AWMFD, and PSCV slopes appear to level off or create a sill, where the conservation of information between the 40 × 40 and 50 × 50 grid sizes is more pronounced. The Number of Patches (NP) for sawgrass, wet prairie, and cattail decreased from 47,009 to 719, 43,204 to 738, and 7,566 to 257, respectively, when looking at the 10 × 10 and 175 × 175 grid sizes. Projected total costs for producing raster based vegetation maps increased from \$192,823.00 utilizing a 175 × 175 grain size to \$59,052,000.00 when using a 10 × 10 grid size (Fig. 6).

Discussion

This study investigated how landscape and class metrics changed as a result of increasing grain size. The objective was to investigate how spatial metrics could potentially be utilized to investigate scale effects to gain insight into ecosystem thresholds for

Fig. 3 Spatial representations of an example area within WCA-3 that depicts the original vector coverage and various grid sizes used in this study. Note: *Green* = Sawgrass; *Blue* = Wet Prairie; *Red* = Cattail; and *White* = Other

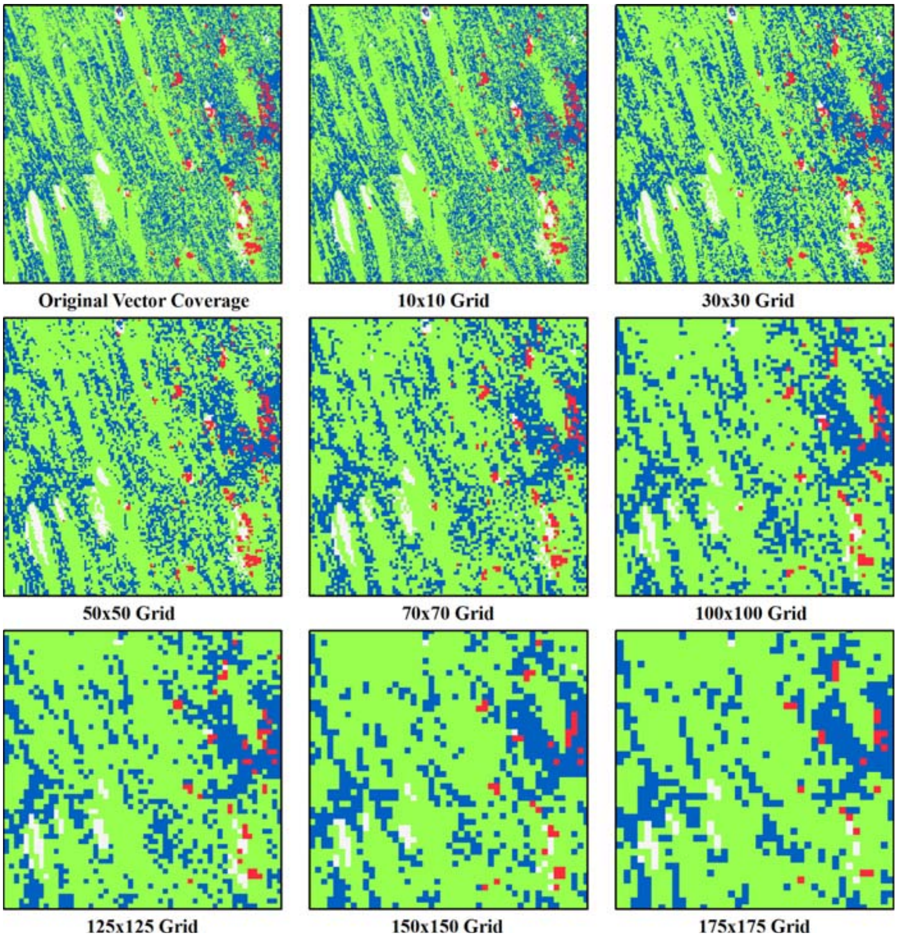

Table 1 List of landscape and class metrics adopted from Wu et al. (2002)

Landscape and class metrics	Abbreviations	Description
Number of patches[a]	NP	Number of patches in landscape
Patch density[a]	PD	Number of patches per km^2
Largest patch index	LPI	Percentage of total landscape area of the largest patch
Total edge[a]	TE	Sum of the lengths (m) of all edge segments
Edge density[a]	ED	Sum of the lengths (m) per hectare (unit: meters per ha)
Landscape shape index[a]	LSI	A unitless measure of class aggregation or clumpiness
Mean patch size	MPS	The mean of all patch areas (unit: ha)
Patch size standard deviation	PSSD	The standard deviation of all patch areas (unit: ha)
Square pixel	SqP	A unitless normalized perimeter area ratio = 1(1/LSI)
Area weighted mean shape index	AWMSI	A unitless measure of irregularity or complexity
Area weighted mean fractal dimension	AWMFD	A unitless measure of irregularity or complexity
Patch size coefficient of variation	PSCV	Measures relative percent variability about the mean

[a] Denotes that these were the only ones used for class metrics

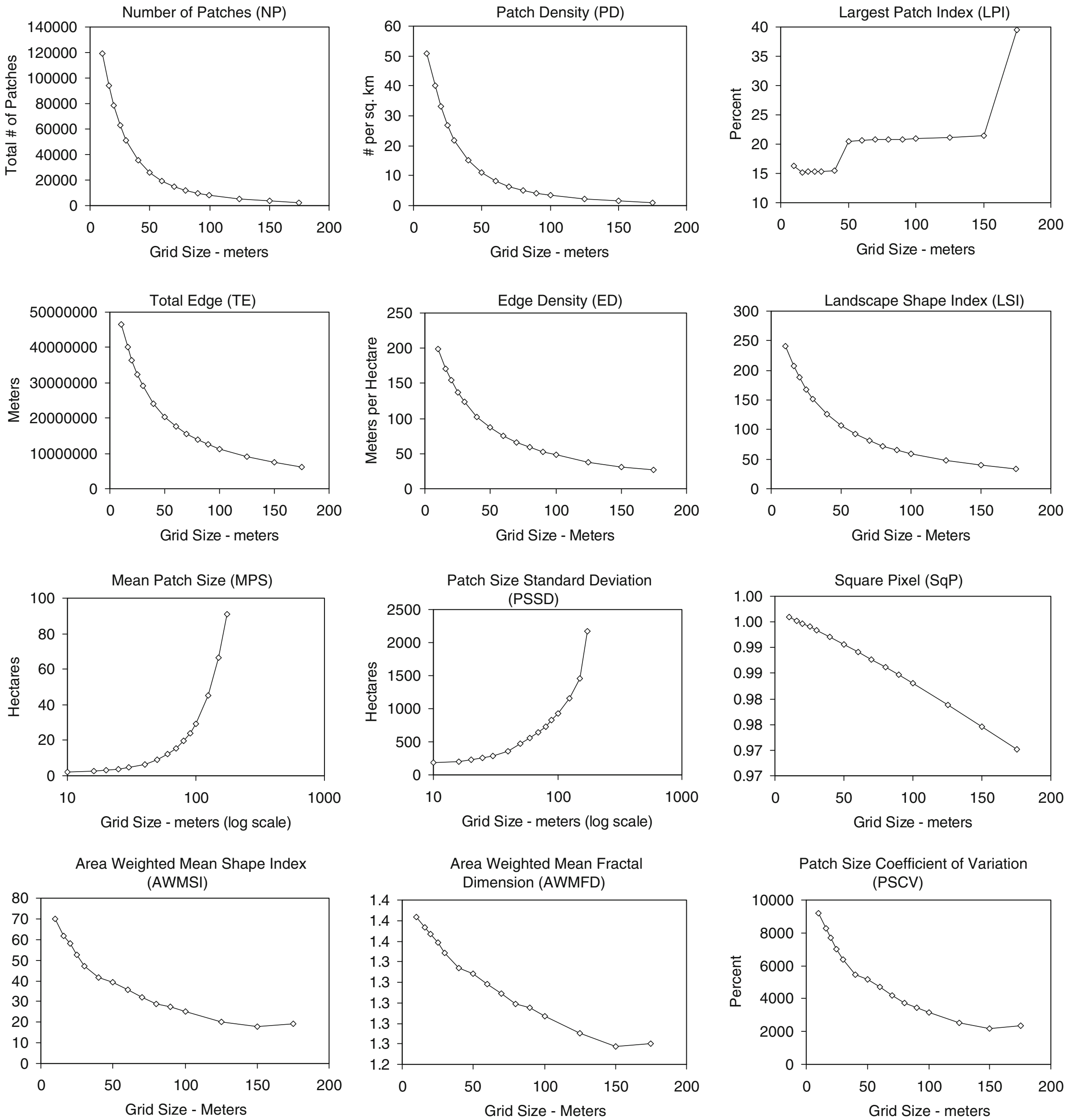

Fig. 4 Landscape metric scalograms with changing grain size

determining a MMU. Wu and Hobbs (2002) recently identified similar key issues that need further investigation in landscape ecology. One issue involved scaling, which for vegetation mapping pertains to the lack of specific methodologies for determining how appropriate scales are established or scaled up or down across heterogeneous landscapes. Another key issue involved the optimization of landscape scale and pattern through the appropriate selection of grain size, to achieve the desired composition and configuration of the landscape being mapped. This current study was confounded by these very same issues.

Hay et al. (2001) describes scale as a 'window of perception' from which a system is viewed and quantified. Changing scale may distort the associated patterns of reality, which can have significant

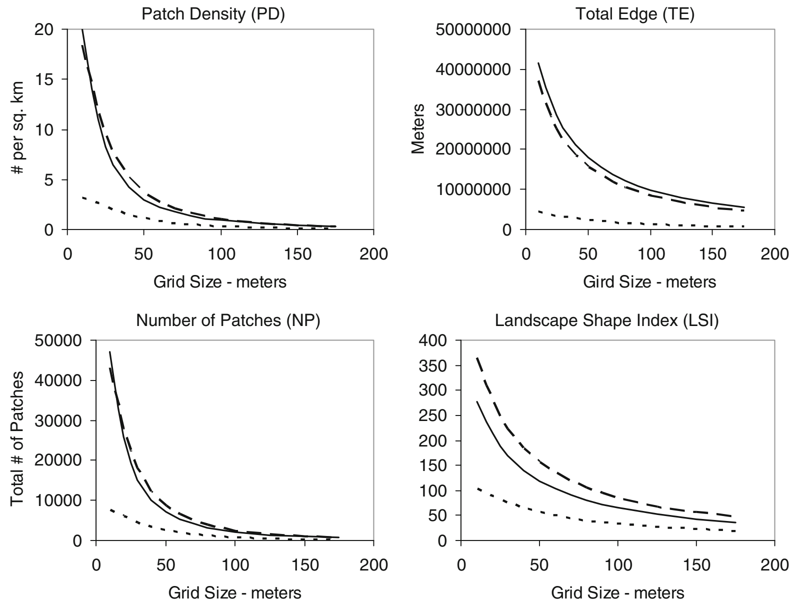

Fig. 5 Class metric scalograms with changing grain size for sawgrass (*solid line*), cattail (*dotted line*), and wet prairie (*dashed line*)

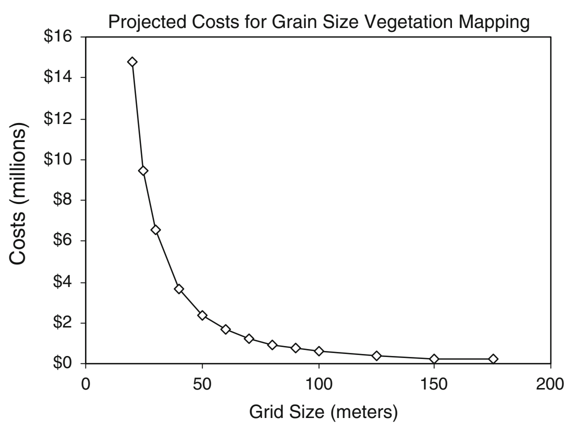

Fig. 6 Projected costs of grain size vegetation mapping. Note: Grain sizes of 10 and 16 vegetation mapping costs were $59,052,000 and $23,067,188, respectively

consequences for understanding such things as fish movements or how birds determine where to forage within the landscape. They also theorize that patterns may change monotonically over a range of grain sizes for a particular phenomenon, and that these represent scale thresholds that may have a significant influence on a process. For the current study, we suggest that this phenomenon may be exhibited in the AWMSI, AWMFD, and PSCV metrics between the 40×40 and 50×50 m grid sizes. This range is where there appears to be an observable leveling along the slope of the line (Fig. 4) or what can be thought of as a conservation of information.

Stohlgren et al. (1997) compared plant diversity patterns from vegetation maps made with 100, 50, 2, and 0.02 ha MMUs in a 754 ha study in Rocky Mountain National Park using four 0.025 ha and twenty-one 0.1 ha multi-scale vegetation plots. They reported that if MMU is too large, some vegetation types appear larger and more contiguous, medium area vegetation types could be reduced or increased in landscape cover, and small area vegetation types become entirely undetectable. They noted that by increasing the MMU, a number of polygons that were recognized at smaller grain size were not recognized at larger grain size. They also were concerned that a major effect of increasing the MMU is that these types of maps may produce complacency in which land managers and/or researchers may assume that additional research, inventory, and monitoring are not a priority. They concluded that when evaluating the effects of MMU, that an initial stratification of homogeneous, heterogeneous and rare habitat types must be conducted and that an evaluation of within-type and between type heterogeneity be investigated to find environmental gradients. These findings are especially applicable to the areas within the CERP boundary (Fig. 1) where many environmental gradients (e.g. nutrient or hydrology based) have been created due to engineering projects of canals, levees and pumps over the past century, which have caused the altering of the landscape. Wu et al. (2006b) utilized landscape indices and suggested that there is a wide range in ridge and slough patterning due to the hydrologic alterations within impoundments of the CERP project area. Wu et al. (1997) also analyzed the spatial patterns of vegetation change within an impoundment in the CERP boundary and were able to quantify the patch dynamics of a rapid invasion of cattail due to a compounding effect of both nutrients and hydrology. There are also many unique habitats within the CERP boundary, such as tree islands (Sklar and van der Valk 2002) which host a rich diversity of flora and fauna. How tree islands are formed, maintained, and are spatially articulated within the landscape is a topic of great concern for researchers working to restore this ecosystem. South Florida also has a sub-tropical climate, which allows for a prolific invasion of exotics (both flora and fauna) (Ferriter et al. 2008), which each invade the ecosystem at different temporal and spatial scales. Understanding how these driving metrics (e.g. hydrology, nutrients), exotic infestations, and natural flora and fauna converge and create gradients at different scales is critical to successful restoration. Further research is needed to determine landscape scales at which these metrics interact and cause change and the optimum mapping scales which allow these changes to be detected.

This current study demonstrates that heterogeneity of vegetation communities from a landscape perspective will exhibit dissimilar patterns with changing scale. Various organisms (e.g. birds, fish, and amphibians) and ecological processes (e.g. soil accretion and subsidence, water and soil chemical cycling, fire) within the south Florida ecosystem also have unique characteristic scales at which they interact within the landscape. Cullinan and Thomas (1992) suggested that studies investigating ecological processes must first be conducted so that these processes are understood, in order to determine appropriate scales at which ecological phenomena under investigation manifest themselves. However, they point out that limitations due to time and money often prevent such studies from being conducted. Others (Qi and Wu 1996; Wu et al. 2006a) also point out that to advance our understanding of spatial processes, it is imperative to first understand and quantify how changing spatial scale affects the results of a spatial analysis of landscape heterogeneity. They further stipulate that the results of all spatial analyses should include an explicit specification of the scale on which the study was based and that whenever feasible, analytical results across a range of scales should be investigated to determine the optimum scale. These types of analyses may provide insight for the selection of an appropriate grain size and therefore reduce scaling uncertainty, and may reduce scale mismatching when investigating metrics operating under different scale dependencies. Understanding this spatial hierarchy within the CERP boundary is critical to determine how spatial dependencies are linked across small scales (e.g. macroinvertebrates), to components of metrics working within medium scales (e.g. fish movement), to metrics that work within larger scales (e.g. bird foraging). This is further complicated by the fact that ecosystem formation is a function of the interactive effects of biological, physical, geological and chemical processes. For instance, interpreting flora and fauna cross scale interactions is often complicated because of synergistic physical cross-scale processes such as seed dispersal by wind, fire, and erosion and the deposition of soil and nutrients by wind and water. These interactions often provide a degree of connectivity between different and disparate parts of the landscape.

In general, environmental modelers have been restricted to using coarser grain data. For instance, Costanza and Maxwell (1994) showed that while increasing resolution provides more descriptive information about patterns, it also increases the difficulty of accurately modeling those patterns. They suggested that these limitations will change with changing technology and modeling skills. Thus, an optimal resolution for a particular modeling exercise with existing technology is one that balances the benefit of increasing data predictability by increasing grain size against the cost of decreasing model predictability with decreasing grain size. These findings support the development of a spatial model, but may be contrary to the optimum grain size that a particular phenomenon is operating under, demonstrating the difficulties of creating ecological models that can predict within specified bounds of certainty. Uncertainty in ecological models is directly related to uncertainty in scaling.

This study supports the findings of Wu et al. (2002) that landscape metric "scalograms" are more likely to be successful for linking landscape pattern to ecological processes because both pattern and process in ecological systems often operate on multiple scales. The current study also incorporates an economic cost for various grain dependant vegetation mapping endeavors. It is the consideration of cost combined with the desire for a specific scale dependant study that at many times determines the spatial grain that is achievable for a vegetation mapping project. This cost factor at times results in vegetation mapping projects being scaled back in extent to meet the scale dependency for a specific fine scale metric. Alternately, the spatial grain is increased which may preclude the data from being compared with finer scale dependant research metrics being collected. Ultimately, the desire is to have the vegetation mapping data meet all scale dependant metrics within budget. It is difficult to define the most appropriate scale of a study as the resolution at which the phenomena of interest operates and are operated upon, may not be immediately apparent. Thus, in most cases, the best practice may be to adopt the highest resolution affordable (Haines-Young and Chopping 1996). This study utilized data from a detailed 234,913 ha mapping project within the CERP boundary but caution should be taken in applying the results from this area to other projects within the CERP boundary. However, this study does provide spatial "scalograms" along with a grain specific economic factor that could be applied within other areas where researchers are designing their landscape based research projects.

Conclusion

The current CERP RECOVER vegetation mapping is being conducted with a MMU or grain size of 50 × 50 m, which equates to approximately 4,369,845 grid cells to be classified for the greater Everglades landscape. The project is a stereoscopic analysis of 1:24,000 scale color-infrared positive transparencies (23 by 23 cm format) utilizing analytical stereoplotters and/or softcopy workstations (Rutchey et al. 2008). Each grid cell is systematically labeled with the major vegetation category observed within the cell. In addition, the classification allows for exotic species to be identified using an additional density class. The density classes are: "monotypic" (greater than or equal to 90%), "dominant mix" (50–89%), or "sparse mix" (10–49%). A grid cell can be labeled with a majority category and also have a "sparse mix" modifier. Any grid cell where more than two categories are noted could end up being labeled as a "sparse mix" majority. Cells that contained exotics where herbicidal treatment had occurred also use the same density class for labeling. Cattail, although not an exotic, is also mapped using the same density class criteria. The selection of the 50 × 50 m grain size was based on several criteria included in this study. The results of this study were that (1) LPI changes abruptly between grid sizes of 40 × 40 to 50 × 50; (2) MPS and PSSD slopes within "scalograms" appear to change between grid sizes of 50 × 50 to 60 × 60 and 30 × 30 to 40 × 40, respectively; and (3) AWMSI, AWMFD, and PSCV slopes appear to level off or create a conservation of information sill at the 40 × 40 to 50 × 50 grid sizes. None of these criteria alone or in combination justifies specifying the selection of an optimum MMU. However, these indices do provide some insight into how some of the metrics are changing with increasing grain size. Another important consideration in selecting the grid size was the composite best professional judgment of a group of experienced scientists who have extensive knowledge from working within the CERP boundary and who also have a vested long-term interest in the outcome of this mapping project. Lastly and often most important, was the cost factor. The current CERP RECOVER vegetation mapping effort is being conducted on a 5 year cycle and will cost approximately 2.4 million dollars over that time period when mapped at a 50 × 50 m grid size MMU. This accounts for a substantial (approximately five percent) portion of the overall CERP RECOVER monitoring and research budget allocated each year for all of the competing metrics that are being studied within the CERP boundary. Decreasing the grain size further was limited by funding. It is fully recognized that this 50 × 50 m grid size MMU will not meet every research scale dependent need of studies being conducted within the CERP boundary. However, it is suggested that this may be the most appropriate MMU, considering the large landscape extent (10,924 square km), the results of this study, the best professional judgment of senior scientists working in the system, and the cost.

The CERP RECOVER vegetation mapping effort utilizing the 50 × 50 m grid size MMU has reduced costs by 65% when compared to a vector approach using a similar MMU. One unexpected result of the grid mapping methodology was that it reveals more landscape heterogeneity. This provides a more realistic depiction of the highly complex landscape such as can be observed when flying over the area. This may be due to the fact that the photointerpreter must view and classify each quarter-hectare grid individually. Further evaluation and analysis is required to quantify these observations, to gain a better understanding of the adequacy of a quarter hectare grid mapping unit and to identify tradeoffs associated with these two mapping methods (vector vs. grid).

In conclusion, the grain size was selected based on a combination of insight from “scalograms”, best professional judgment, and costs. This research is intended to stimulate further studies on how scale dependencies can be detected between various metrics being studied within the CERP boundary.

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