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Vegetation Condition & Vegetation Mapping I.
Critical Global Review of Approaches to Assessment of Vegetation Condition

Report to
Science Division of the Department of Environment & Conservation, Government of Western Australia

by

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Executive Summary:

This report reviews, in critical manner, theoretical background and methodical tools of assessment of vegetation condition. Two basic approaches have been identified – the class-based approach (based on concept such as hemeroby and naturalness and including the Favourable Conservation Status adopted by the European Union as well as the Australian VAST assessment, and index-based approaches (including most of the Australian East Coast assessment schemes such as Habitat Hectares, BioMetric and BioCondition. All index-based approaches reviewed incorporate highly problematic calculations of final condition values (indices). It appears that the concept of VC had been given much more attention in Australia than anywhere in the world. Implementing monitoring and remote-sensing tools outside Australia is also rare.

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Aims of this Report & Terms of Reference

It is the aim of this report is to provide an international review of the concept of "vegetation condition" (and related concepts) and to address several vegetation mapping related issues. The particular Terms of Reference read:

Review of international literature on what is the definition of vegetation condition and how condition is assessed and quantified overseas. Particular attention should be directed towards the tools and methods used to assess vegetation conditions, in particular remotely sensed tools, what products (e.g. maps) are used to present/depict the condition of vegetation and the relationship that condition assessments and presentation products have to vegetation maps. This review should include exemplars or case studies of how vegetation condition is assessed in a few overseas jurisdictions, particularly those were the approach employed is efficient, rigorous and worthy of consideration for adoption in Western Australia.

Critical Worldwide Review of the Concept *Vegetation Condition*

1. Vegetation Condition: What's in the Name?

There is perhaps only one constant in nature – the change. World around us undergoes changes at various spatial and temporal scales. Much of these changes are natural—obey natural laws and pursue natural pathways—still much of these changes are caused by us. We, the human society, are honestly interested in understanding these changes to assure in the first place (let us admit frankly) our own well-being and then perhaps the well-being of other organisms sharing this world with us. As a result of the constant change, entire biomes, landscapes, ecosystems, rangelands, rivers, wetlands, forests, vegetation, biodiversity, plant and animal communities and the like change their face – pass from one state of condition to another. Naturally, the "condition" has a meaning only from anthropocentric point of view: good or bad, improving or worsening, progressing or regressing… Because we are interested to know the condition our environment or of nature resources we need, the "condition" has become subject of both academic curiosity and of great interest to those meeting decisions about the wise use (conservation including) of natural resources.

Vegetation condition (further often referred to only a VC) is a complex concept, in fact so complex that it could qualify as "non-concept" (Hurlbert 1971) or at least "cluster concept" in Peters' (1991) terminology. It is studied by scientists, applied by conservationists, forest and rangeland managers and many other of the kind, and it has found its way into vocabulary of politicians too. Hence it has been used (but also misused and abused) by many parties – all adding to the complexity of understanding what it really is and what it is good for.

Gibbons et al. (2006) suggested, and many other agreed, that there is no standard definition of vegetation condition. This lamentable condition goes in the first place on the account of the complexity of the ways students of vegetation conditions viewed the aims of vegetation condition assessment. A single site might be assessed from more than one perspective (see Gibbons et al. 2006, Keith & Gorrod 2006, Hnatiuk et al. 2009), including aesthetics values, various aspects of ecosystem services (such as pulp productivity and regeneration status in forests, grass productivity and regeneration ability in rangelands, carbon sequestration capacity) as well as biodiversity conservation, including level of intactness, species richness, structural diversity and the like.

The aim of this report is to present a global review of VC from a specific point of view – ***status of vegetation from the point of view of biodiversity conservation***. Biodiversity being itself is a very complex term and in my understanding included all level of biotic complexity spanning genes to landscapes. The diversity of species and plant functional types, structural elements of vegetation (such as layers) and diversity of ecological processes are the key elements of the VC theory and methodology.

In this light I attempt here to define Vegetation Condition, in operational way by clear setting of scaling and conditional parameters, as:

Status of naturalness of any vegetation patch or complex, as assessed against a conventional benchmark from point of composite view of species composition, vertical and horizontal structure stands, processes generating vegetation patterns and dynamics, and the ability to provide ecosystem services securing maintenance of biodiversity.

Some of the alternative definitions of VC (albeit not all pertinent to biodiversity conservation) are presented in Table 1.

There are a number of terms and concepts directly relevant (underlying and often synonymous) to the concept of VC. These include intactness, ecosystem health, naturalness, hemeroby, degradation, desertification and the like (see Table 2 for list of literature sources suggesting, analysing and applying these concepts). Some of these terms, especially those which play a central role in defining some approaches to VC, will be encountered in this Report.

This Report will not review sources which understand vegetation condition as remote-sensing related index, for instance defined for instance as ***"the reduction of multispectral scanning measurements to a single value for predicting and assessing vegetative characteristics"*** (see Natural Resources Canada 2009). Examples of such characteristics include plant leaf area, total biomass, fresh and dry above-ground phytomass, chlorophyll content, plant height, percent ground cover by vegetation, grain or forage yield and general plant stress and vigour. The measurement of these remote-sense characteristics

Table 1. Selection of definitions of vegetation condition (VC) and related concepts. Based on Gibbons & Freudenberger (2006) and expanded.

Source	Definition	Focus
US Fish & Wildlife Service 1980	The ability of key habitat components to supply the life requisites of selected species of wildlife.	integrity of ecological functions
Pickup et al. 1994	The sustained ability to produce forage from rainfall.	rangeland condition; biomass production (fodder)
Tongway & Ludwig 1997	A position of particular rangeland site along continuum depending on the judgment of the value of the landscape for given purpose.	range condition/ general attempt for overarching definition/ recognition of continuous nature of VC
Perkins 2002	The predicted degree to which the ecosystem retains a capacity to recover after the removal of the source problem and application of restoration treatments	ecosystem resilience/ ecological functions
Jansen et al. 2004	The degree to which human-altered ecosystems diverge from local seminatural ecosystems in their ability to support a community of organisms and perform ecological functions.	ecological functions
Gorrod 2006	The capacity of a site to provide habitat for all the indigenous species that may reasonably be expected to use it.	site occupancy/biodiversity
Parkes et al. 2006	The degree to which the current vegetation differs from a benchmark representing an average characteristics of a mature and apparently long-undisturbed stand of the same vegetation community.	relative vegetation quality
Hnatiuk et al. 2009	Condition refers to the state of vegetation relative to some specific benchmark.	relative vegetation quality

is usually remote to understanding of vegetation condition from the biodiversity point of view.

Further this Report will not deal with vegetation conditions assessment aimed at other than biodiversity conservation issues. For instance, grasslands (vegetation dominated by graminoids, often with scattered shrubs and trees as in case of savanna ecosystem) deliver, besides the obvious conservation-relevant services such as habitats of rare and endangered species and plant communities, other economically important ecosystem services. Many grasslands serve as rangelands, hence the status of biomass and production of the grass component is the usual focus of vegetation condition assessments. Forests are a source of resources of manifold type and economic and cultural importance. Assessments of the conditions of the forests from the point of view of regeneration ability, production of timber and the like have been logical foci of the VC assessments in these ecosystems. I have also refrained to review methods of vegetation assessment in aquatic environments (such as shallow seas, estuaries, lakes, seasonal wetlands) or similar micros-scale vegetation types (rock pools, rock and cliff faces, epiphytic vegetation and the like. All these require special approach and tools, and deserve special attention at later stage.

Tab. 2. List of basic concepts pertinent to vegetation condition and relevant global and Australian references.

Concepts	Global References	Aussie References
Anthropization/synanthropization	Faliński 1969, 1988, 2000; Kostrowicki 1972, Kunick 1974; Kornaś 1982; Celesti Grapow et al. 1989	
Biodiversity intectness	Scholes & Biggs 2005; Mace 2005; Rouget et al. 2006; Nielsson et al. 2007	
Biological/ecological integrity	Karr 1991; Woodley et al. 1993; Angermeier& Karr 1994; Majer & Beeston 1996; Hunter 2000; Pimentel et al. 2000; Andreasen et al. 2001; Troyer 2002; Czech 2004; Bleby et al. 2008; Timko & Innes 2009	
Ecosystem/landscape health	Costanza et al. 1992; Dahms & Geils 1997; Callicott 1999; Hunter 2000; Jensen et al. 2000; Montefalcone 2009	Bastin et al. 1993, 1998; Pickup et al. 1994; Tonway & Ludwig 1997; Karfs et al. 2000, 2004; Whitehead et al. 2000; Barnes & McCoull 2002; Ludwig et al. 2002, 2006, 2007; Bastin & Ludwig 2006; Stone & Haywood 2006; Jafari et al. 2007
Favourable conservation status	CEC 2004, 2009; Ellmauer 2005; Šeffer et al. 2005; Mehtälä & Vourisalo 2007; Søgaard et al. 2007; ETCBD 2008; Zingstra et al. 2009	
Habitat quality/suitability	US Fish & Wildlife Service 1980; Burgman et al. 2001	Pressey et al. 2000; Parsons et al. 2004
Hemeroby	Jalas 1953, 1955; Ellenberg 1963; Sukopp 1969, 1972, 1976, 1997; Miyawaki & Fujiwara 1975; Blume & Sukopp 1976; Dierschke 1984, 1994; Schlüter 1987; Kowarik 1988, 1999a, b; Frank et al. 1990; Jurko 1990; Grabherr et al. 1995, 1998a, b; Lindacher et al. 1995; Koch & Kirchmeier 1997; Koch et al. 1997; Steinhardt et al. 1999: Hill et al. 2002; Klotz et al. 2002; Li et al. 2002; Yang et al. 2002: Acosta et al. 2003; Béguin & von Felten 2003; Fanelli & De Lillis 2004; Ziarnek 2007; Fanelli & Testi 2008; Hornschuch & Riek 2009; Stoll 2005, 2007; Testi et al. 2009	
Land degradation/desertification	Bastin et al. 1993; Feoli et al. 2003	
Natural authenticity	Clewell 2000	

Naturalness	von Hornstein 1950, 1954; Westhoff 1952; Pfadenhauer 1976; Seibert 1980; Schafale & Weakly 1990; Anderson 1991; Hoerr 1993; Hunter 1996, 2000; Corner 1997; Edarra 1997; Kim & Lee 1997; Pedrotti & Minghetti 1997; Mátyás 1998; Schirmer 1999; Blasi et al. 2001, 2003; Brentrup et al. 2002; Kim et al. 2002; Li & Kräuchi 2002a,b, 2003a, b; Povilitis 2002; Bartha et al. 2003, 2005, 2006; Steinmeyer 2003; Leard 2004; Machado 2004; Machado et al. 2004; Siipi 2004; Bölöni et al. 2005, 2008; Parviainen 2005; Willis & Birks 2006; Ridder 2007a, b; Czúcz et al. 2008; Ferrari et al. 2008; Guarino et al. 2008; Reif & Walentowski 2008; Wehenkel et al. 2009	
Rangeland/veld condition & health	Dyksterhuis 1949; Foran et al. 1978; Vorster 1982; Bosch & Janse van Rensburg 1987; Bosch & Kellner 1991; Bosch & Gauch 1991; Bosch et al. 1992; Gibson et al. 1995; Gibson & Bosch 1996	Bastin et al. 1993, 1998; Lange et al. 1994; Pickup et al. 1994; Wallace et al. 1994; Tonway & Ludwig 1997; Karfs et al. 2000, 2004; Whitehead et al. 2000; Gould et al. 2001; Bastin & Ludwig 2006; Jafari et al. 2007
Reference condition	Aronson et al. 1993, a, b, 1995; Brinson & Rheinhardt 1996; Fule et al. 1997; Haila 1997; Hunter 1997; Bragg 2002; Laughlin et al. 2004; Muxica et al. 2006; Tison et al. 2007	Wilson 1984; Oliver et al. 2002; Parkes et al. 2003, 2004; McCarthy et al. 2004; Pickett & Parker 1994; Prober et al. 2002a, b; Gibbons et al. 2008
Resilience	Westman 1978	Perkins 2002
Riparian & wetland condition	Rheinhardt et al. 2007	Janssen et al. 2004; Parsons et al. 2004
Vegetation condition		Kaesehagen 1994; Keighery 1994; Wallace & Furby 1994; Hopkins 1999; Environment Australia 2000, 2001; Oliver 2002; Oliver et al. 2002; State of Victoria 2002; Cadman 2003; ESCAVI 2003a; Oliver & Parkes 2003; Parkes et al. 2003, 2004; Landsberg & Crowley 2004; McCarthy et al. 2004; Eyre et al. 2005, 2006; Gibbons et al. 2005, 2008, 2009; Sharp 2005; Gibbons & Freudenberger 2006; Gorod 2006; Higgins 2006; Keith & Gorod 2006; Michaels 2006; Newell et al. 2006a, b; Parkes & Lyon 2006; Wallace et al. 2006; Thackway & Lesslie 2005, 2006, 2008; Thackway et al. 2005, 2006; Lesslie et al. 2008; Hnatiuk et al. 2009; Gorrod & Keith 2009
Wilderness quality		Klein et al. 2009

2. Many Faces of VC: Classification of Approaches

In the sequel I shall review various approaches to VC (often quite similar in essence, but called very different names in different parts of the world. The origins of the concepts and their meaning will be featured, an example or two of applications of the regional approaches will be presented, and finally advantages and drawbacks of these approaches will be listed and argue in the light of (a) scientific soundness and consistency, (b) feasibility to address issues of biodiversity conservation, and (c) ability to translate the assessment into vegetation condition maps, and (d) feasibility of long-term monitoring (repeatability of the assessment and its mapping).

Any global review of the approaches to VC would not be complete without discussing the ways how VC has been handled in Australia. Indeed Australia is a global leader in the field of nature conservation and management, and it is therefore not surprising that the concept of vegetation condition received much attention here. Unique flora and fauna of the continent and large tracks of nearly pristine vegetation which experienced in the past only impact of native fauna and traditional nature-close aboriginal land care practices are trademarks of Australia's nature. Growing population along the continent seaboards and the growing demands of the population for resources poses threats to the Australian wilderness. Climate change (and all associated disturbances) has become the leading matter of concern not only about the fate of coastal settlements, agricultural production, changing fire regime or water supply, but also to protection of biodiversity and sustainable use of renewable nature resources such as vegetation. Population growth and climate change will have effect on the condition of vegetation cover. The need for new, repeatable and effective vegetation surveys, including the assessment of the vegetation condition (and possible trajectories of its change) and vegetation mapping (both of current state of the vegetation cover as well as predicted changes under different scenarios) shift into the center of attention of the society.

The Australian approaches to vegetation condition have been featured in great details in a recent report by Bleby et al. (2008). In the sequel I shall only summarise major highlights (see also Table 3) and provide critical comments on the various methodologies not addressed in the Bleby et al. (l.c.).

There are basically two dichotomies which can assist classifying the approaches to VC: (1) ground-based versus remote-sensed (reflecting nature of data collection and sampling detail), and (2) class-based versus index-based (reflecting the nature of assessment criteria and the ways of handling them). The latter dichotomy reminds of the classical and in the past passionately discussed dichotomy between classification and ordination (see Whittaker 1972 and references therein).

2.1 Hemeroby, Naturalness, Synanthropization

2.1.1 Origins and Principles

The terms such as hemeroby, synthropization (also called anthropization or anthropogenization) were born in Europe—in landscapes heavily impacted (over millennia and over large scales) by human civilization. Some say that every stone in Europe has been either turned over by plough or bloodied by wars uncountable many times. Much of the vegetation cover in southern, central and western Europe is either man-made or man-impacted. Only northern Europe (Fennoscandia, Arctic islands) and Eastern Europe (especially NE Russia), regions having low-density population, are supporting vast tracks of wilderness.

Much of the rest of European (non-synanthropic) vegetation in densely populated parts of Europe has been seriously impacted by man. The degree of this impact has been addressed by several formal concepts of which ***hemeroby*** (and related concepts – see below) became well established and is found still in use in many European countries (Table 4).

Tab. 3. A survey of vegetation condition and rangeland asessment approaches used in Australia. Bench = Benchmark using (Y) or non (N); Type of approach: C = class-based, I - index-based.

Political Unit	Method	References	Bench	Type	Note
Commonwealth	VAST	Thackway & Lesslie 2005, 2006, 2008	N	C	7-degree condition states, incl. States I through III (Residual, Modified, Transformed, resp.) pertaining to Native Vegetation Cover; the States IV through VI (Replaced-Adventive, Replaced-Managed, removed) pertain to Non-native Vegetation Cover) and State 0 designates Naturally Bare area; approach similar to the European hemeroby concept; **the calculation of final VAST score at mapping stage is problematic because of the averaging of nominal values**
Western Australia	Keighery Condition Scale	Keighery 1984	Y	C	6-category scale: pristine (benchmark), excellent, very good, good, degraded, completely degraded; rating refers to change in structure and species composition; does not serve non-native vegetation
Western Australia	Kaesehagen Condition Scale	Kaesehagen 1994	N	C	4-category scale (very good to excellent, fait to good, poor, very poor) based on % estimate of native flora occurrence, presence of weeds and vegetation structure
Western Australia	Coote Condtion Scale	Coote 2001	N	C	4-category rating: (1) pristine to slightly degraded, (2) degraded, (3) erosion prone to eroded, (4) eroding ditch to weed infested drain; other assessment factors (presence/absence of understorey and groundcover, age of vegetation etc.) also considered; obviously addressing only limited span of vegetation types
South Australia	Land Condition Index	Lange et al. 1994; Gould et al. 2001	N	I	various condition ratings using 3-category scale (high disturbance, moderate distiurbance, low disturbance), LCI calculated as weighted average (product of multiplication of % of sample points for each condition rating by the rating); **calculation procedure requires scrutiny**
Northern Territory	VAST	see Commonwealth	N	C	see above
ACT	VAST	Sharp 2006	N	C	combination of Botanical Significance Rating (BSR) considering cover, richness, and rarity of plant species assessment of vegetation structure; 5-degree assessment scale
Queensland	BioCondition	Landsberg & Crowley 2004; Eyre et al. 2005, 2006, 2008	Y	I	in all respect very similar to HH approach (see below) by using combination of site-based and landscape-based descriptions, weighting and similar protocol for calculation of the final habitat score; **it therefore suffers from the same calculation problems as HH**
New South Wales	BioMetric	Gibbons et al. 2005	Y	I	very similar in many aspects to HH approach; **the calculationof the final score is equally problematic as in HH**
New South Wales	Zerger et al.s Method	Zerger et al. 206	Y	I	similar to HH in assigning a score the value recorded for each variable on each plot (0 to 3), summing these scores across all variables for each plot, and scaling the summed values within a range (in this particular case from 0 to 10); **highly problematic calculation procedure (see text for details)**
Victoria	Habitat Hectares (HH)	Parkes et al. 2003, 2006	N	I	a large set of indicators are rated using ordinal and nominal scales, weighted, and summed up transformed ("standartized") values; **highly problematic calculation procedure (see text for details)**
Tasmania	Habitat Hectares (HH)	Michaels 2006	N	I	see the Victorian HH approach: TASVEG toolkit used for assessment
Tasmania	Health of Tasmania's Forrested Bush	Barnes & McCoull 2002	N	C?	3-category scale with more detailed rating involved

The term hemeroby (from Greek *hemeros* = cultivated) was coined by Finnish botanist Jalas (1953, 1955) and was used to assess level of “naturalness” (native versus alien status) of species. The concept has been further developed and by Sukopp (1969, 1972, 1976), Blume & Sukopp (1972), Dierschke (1984), Kowarik (1988, 1999a, b) and Koch & Kirchmeier (1997). Hemeroby has been related to land use to become incorporate din so called Life Cycle Assessment methodology (Brentrup et al. 2002). Hemeroby found many applications in works of European vegetation ecologists and biogeographers. An exhaustive list of all publications goes beyond this task, however quite exhaustive accounts of literature sources and reviews of the concept are found in Schlüter (1987), Kowarik (1988, 1989a, b), Brentrup et al. (2002) and Li et al. (2002). Among the recent applications of hemeroby count papers by Hill et al. (2002), Acosta et al. (2003), Béguin & von Felten (2003), Fanelli & De Lillis (2004), Ziarnek (2007), Ferrari et al. (2008), Fanelli & Testi (2008) and Testi et al. (2009).

In Europe scales of hemeroby found their way to standard ecological manuals designed for quick vegetation assessment (Jurko 1990 in Slovakia; Frank et al. 1990, Lindacher 1995, Klotz et al. 2002 in Germany; Ellenberg et al. 1991 in Central Europe).

Because of its simplicity and intuitive features, the hemeroby assessment was imported (by Europeans or by their non-European students) to Japan (Miyawaki & Fujiwara 1975), Korea (Kim & Lee 1997, Kim et al. 2002) and Chile (Stoll 2005, 2007).

“Naturalness” has been one of the core (non-concepts) of nature conservation and management research (and application). Protecting natural environment, natural ecosystem sounds very logical especially in days when nature

Tab. 4. Various scales used in assessment of hemeroby, naturalness, and related concepts such as VAST.

Scheme	Sources	Description	Country
Hemeroby	Sukopp 1969	4-degree scale for habitats (euhemerobic, meso-hemerobic, oligohemerobic, ahemerobic); based on % of occurrence of neophytes (alien) species related to1 sq.km) and % loss of species related to 1000 sq.km)	Germany
	Blume & Sukopp 1976	7-degree scale for habitats; similar to Sukopp (1969), but euhemerobic category subdivided into 3: metahemerobic, polyhemerobic, euhemerobic)	Germany
	Kowarik 1990a, b	11-degree scale for habitats building on 7-degree scale, but introducing several transition degrees such as meo- to β-auhemerobiv, β-ehemerobic to α-euhemerobic, α-euhemerobic to polymemerobic)	Germany
	Koch & Kirchmeier 1997	9-degree scale for forests (polyhemerobic, α-euhemerobic, β-euhemerobic, α-mesohemerobic, β-mesohemerobic, α-oligohemerobic, β-oligohemerobic, γ-oligohemerobic, ahemerobic)	Austria
	Kim et al. 2002	11-degre scale based on dichotomy between anthropogenic and wilderness status and further involving geographic distribution and traits of constituent species	Korea
Naturalness	von Hornstein 1950	5-degree scale (natural, semi-natural managed, relatively unnnatural managed, not natural managed, artificial)	Germany
	Westhoff 1951	4-degree scale (natural, subnatural, seminatural, cultivated)	Netherlands
	Ellenberg 1963	8-degree scale (virgin, natural, relatively near-natural, relatively unnatural, not natural, artificial)	Central Europe
	Seibert 1980	5-degree scale (natural, nature-close, conditional nature-distant, nature-distant, artificial)	Central Europe
	Dierschke 1984	5-degree scale (natural, near-natural, semi-natural, relatively unnantural, artificial)	Central Europe
	Loidi 1994	10-degree scale using climax or potential natural vegetation as benchmark	Spain
	Grant 1995	4-degree scale (natural, subnatural, seminatural, cultivated); states verbally identical with Westoff 1951	
	Tüxen 1956	5-degree scale	Germany
	Tüxen 1968	4-dgeree scale	Germany
	Faliński 1969	5-degree scale (original, natural, semi-natural, pro-synanthropic, eu-synanthropic)	Poland
	Pfadenhauer 1976	5-degree scale (natural, near-natural, semi-natural, non-natural, artificial)	Germany
	Edarra 1997	10-degree scale (0 standing for area highly urbanised, 10 for mature forests, however withoiut further detaiuls of definition of othr degrees)	Spain
	Machado 2004	11-degre scale based on combination of criteria such as presence/performance of biotic (native and exotic) elements, artificial elements (incl. artefacts and pollutants), inout of energy and/or matter, physical alterations, extraction of elements, level of fragmentation and dynamics (water and general)	Spain
	BMVEL 2004	5-degree scale based on share of alien/native species (very near-natural, near natural, relatively near-natural, strongly cultural, cultural)	Germany
	Schirmer 1999	6-degree scale based on share of alien/native species (non-native, native to a ceryain extent, relatively near-natural, near-natural, very near-natural and & b)	Germany
	Blasi et al. 2001	14-degree scale ranging from "extraction area" (meaning: mining area) to "broad-leaved woodland and pretending to depict increasing "proximity to mature vegetation"	Italy
	Guarino et al. 2008		
	Ferrari et al. 2008	5-degree scale (urbanised, agricultural, smei-natural, sub-natural, natural), pretending ordinal nature	Italy
VAST	Thackway & Lesslie 2005	7-degree scale incl.: 0: naturally bare, I: residual, II: modified, III: trsnaformed (all valid for native vegetation extent), IV: replaced-adventive, V: replaced-managed, VI: removed (all for non-native vegetation extent); non-quatified (subjective) assessment procedure	Australia
	Thackway & Lesslie 2006		
	Thackway & Lesslie 2008		
	Thackway et al. 2005		
	Thackway et al. 2006		
	Lesslie et al. 2008		

(wilderness, natural ecosystems) give way to expanding “noosphere” (Michalko 1974), anthropogenic biomes (Alessa & Chapin 2008). What is natural, pristine and what not has been subject of discussions among conservation biologists (Anderson 1991, Hoerr 1993, Comer 1997, Haila 1997, Hunter 1997, Povilitis 2002), palaeoecologists (Willis & Birks 2006), vegetation (especially) forest ecologists (von Hornstein 1950, Ellenberg 1963, Dierschke 1984, Koch & Kirchmeier 1997, Koch et al. 1997, Schirmer 1999, Bartha et al. 2003, Machado 2004, Parviainen 2005, Reif & Walentowski 2008, Wehenkel et al. 2009), and ethics researches and philosophers (Rolston 1986, Hunter 1996, Ridder 1997a, b, Leard 2004, Siipi 2004) etc.

Machado's (2004) "index of naturalness" does not actually qualify as index (a single value expression). It consists of a 10-degree scale where each degree is representing a nominal state (as also admitted by the author of the concept), defined on basis of presence/prominence of biotic and artificial 'elements" (species, artifacts, pollutants), energy input, physical alterations, extraction of elements (?), level of dynamics, and dynamics (Fig. 1). Machado's approach does not differ much form the hemeroby system, except perhaps for the fact that it does not explicitly invoke a theoretical benchmark.

Index	Basic elements		Artificial elements		Energy or Matter Input	Physical alterations	Extraction of elements	Level of fragmentation	Dynamics	
	Native	Exotic	Artifacts	Pollutans					Water	General
10	(almost) Exclusively	None or insignificant	None or insignificant	None or insignificant	None, only natural	None	Only natural vectors	None or insignificant	Free running, natural	Natutal
9	Dominant	Some irrlevant effect	Punctual, irrelevant	Possible, irrelevant	None, only natural	None or irrelevant	None or irrelevant	None or insignificant	Free running, natural	Natutal
8	Dominant but altered	Concentrated or extended low impact	Occasional, some roads	Occasional, biodegradable	None, only natural	None or irrelevant	None or some renewing resources	None or irrlevevant	Free, natural, irrelevant use	Natural, little alteration
7	Diminished but dominant	Settle or dominating, widespread	Scarce (roads and buildings)	Occasional/ regular biodegradable	Irrelevant	None of scarce	Moderate renewing resources	None or low, no qualitative effects	Minor alterations	Natural, little alteration
6	Reduced, possible minority	Wild, occas. dominant, widespread	Scarce or aggregated	Low impact, biodegradable	Occasional, not dominant	None or minor (roads)	Renewing resources, limited matter	None or mdoerate	Deviation, no significant management	Natural, eventually accelerated
5	Managed but altered	Cultivated/ ranged but not forced	Conspicuous, but not dominant	Water and soil slight	Low, regular, occasional or periodic	Moderate (stone walls)	Sustainable, possible matter (low)	None or relevant (patchwork)	None or little management, passive	Oriented, but self-sustained
4	Intermixed, patchy or in corridors	Dominant, usually forced	Important presence	Water and soil, moderate	Moderate, determining factor	Important (channels terraces)	Regular, more intense (export)	Moderate, with or without	Important management, event. input	Forced by man
3	Notable loss	Abundant or not, patchwork	Abundance	Water ans soil intense, air moderate	Intensive, dominating factor	Extended, excavations included	Moderate to very intense (mining)	Intense, very extended	Soft or hard management, extra inputs	Very forced, unconnected, dependent
2	Scarce	Abundant or not	The majority	Water and air permanent	Intensive, important dependence	Extended, excavations included	Variable (waste)	Very intense, no corridors	Intensive management, extra inputs	Dependence from external inputs high
1	Vestiges or absent	Widespread in gardens, confined	Clear dominance	Water and air severe	Very intensive, absolute dependence	Almost full modification (little soil)	Variable (waste)	Maximal	Full control, extra inputs	Fulle external dependence
0	Absent/ irrelevant	Absent/ irrelevant	Almost/ all	Variable	Total dependence	Variable	Variable	Not applicable	Variable or closed	Artificial, conducted

Fig. 1. Interpretative matrix of criteria leading to definition of degrees of naturalness (redrawn after Machado 2004).

Concepts such as synanthropization or anthopization/anthropogenization have dominated vegetation-ecological and biogeographical literature in Poland (for reviews see Faliński 1969, 2000, Kostrowicki 1972, Kornaś 1982) and Germany (for reviews see for instance Sukopp 1969) especially for the last 30-40 years of the 20th Century. These terms reflect the central position of man (in old Greek "anthropos" relates to "man") and imply the effect of man's activities on vegetation cover. Synanthropization stands either for *processes of man's influence on vegetation* (disturbance of plant cover, changes in competitive hierarchy leading to promotion of certain native species with weedy tendencies, introduction of alien species leading often to total change of species composition etc.). Synanthropization may also stand for *level of man's influence on vegetation*, hence offering a counterpart to the concept of naturalness. The processes of synanthropization brings about changes to natural vegetation and create opportunities for formation of new vegetation constructs, including artificial (purely man-made on purpose) vegetation (such as plantations, cultures on arable fields), or spontaneous vegetation which further perpetuation appears possible only trough continuing human influence – so called synanthropic vegetation. Terminologically interesting odd-ball here are so called 'synthetic plant communities' which may suggest transitional phases in the degeneration of native plant cover by introduction of strongly competitive aliens (Bridgewater 1988). This type of vegetation, found especially in urban environments and arable fields, have been subject to studies of many research teams especially in Europe (see Faliński 1966, Kunick 1974, Hejný et al. 1979, Mucina et al. 1984, 1993, Sukopp et al. 1990, Kopecký & Hejný 1992, Jarolímek et al. 1997 for selection of important monographs and compendia).

In terms of mapping the level of human impact on vegetation, the work of Faliński (1975) stands out. His map of anthropogenic changes features the vegetation of Poland (1:2,000.000) mapped using 7 grades of "vegetation transformation"—each mapped polygon is judged and assigned to a degree on basis of complex ratio between the natural and synanthropic vegetation. Since the definition of the "degrees" is quite non-specific, construction of such map was complex process of collation of expert opinion. Modern way of approaching this issue would be mapping of landscape indices based on remote-sense land-use categories.

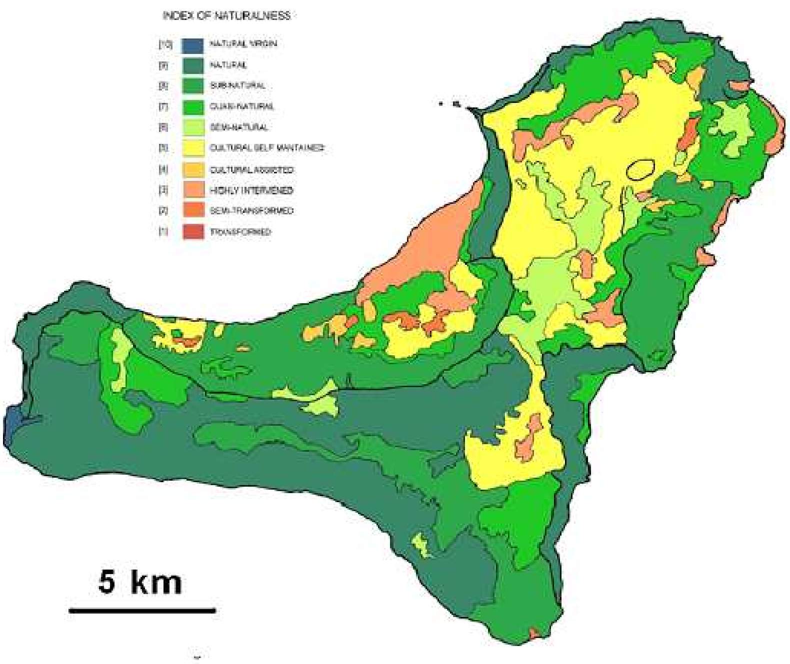
2.1.2 Mapping Hemeroby and Naturalness

Once a vegetation patch had been assigned to a degree of hemeroby or naturalness and a map of vegetation featuring the assessed vegetation is available, there is no problem to express the hemeroby/naturalness in spatial terms. An example of such map is given in Fig. 2. which is base don Machado's "index of naturalness" and features the vegetation of the Canary island of Hierro. Kim & Lee (1997) also mentioned that the results of their "Multicriterion Matrix Method" assessments could be mapped.

2.1.3 Problems and Ailments of the Hemeroby Approach

Choice of Benchmarks (Reference Condition)

*Reference state (*or *"reference condition"* or "ecosystem of reference") as benchmarks for comparisons or conservation and ecological restoration actions is theoretically very contentious and sparked many interesting exchange of opinions (see for instance Aronson et al. 1993a, b, Pickett & Parker 1994, Aronson et al. 1995). It would remain, still for the time being, also in concepts of hemeroby or naturalness which implicitly or explicitly involve a natural benchmark. Because of the obvious role of man and its large-scale economic landscape-shaping activities (especially agriculture and silviculture, urbanization) the natural status of vegetation prior to onset of those large-scale activities has been set as benchmark. For instance Hopkins (1999) in an effort to coin a hierarchical and multipurpose VC assessment framework to cater for different



[10]	Natural virgin system; only natural elements and processes. Possible anecdotal presence of negligible or hardly noticeable anthropic elements, or totally insignicant physical-chemical pollution coming from exterior anthropic sources
[9]	Natural system; presence of few exotic biological elements (no qualitative effects); minimal articial infrastructure, temporary or removable. Physical-chemical pollution absent or of no signicance
[8]	Sub-natural system; possible extended presence of wild exotic species, but not dominant (low impact); articial elements located, not extensive. Occasional pollution processed by the system (does not go beyond resilience). Possible minorextraction of renewing resources. Fragmentation irrelevant. Natural dynamic little altered
[7]	Quasi-natural system; extensive anthropic activities of low physical impact; facilities if present, dispersed, not connected; wild exotic species well established but not dominant; natural structures modied but not distorted (re-location of physical or biotic elements). Moderate extractions, if present. Little alteration of water dynamics
[6]	Semi-natural system; anthropic infrastructure scarce or concentrated; possible dominance of wild exotic species; native elements considerably reduced. Occasional addition of energy and/or extraction of renewable resources or of non-relevant materials. General dynamic still controlled by natural processes. It may include abandoned cultural systems undergoing natural recovery
[5]	Cultural self-maintained system; processes conditioned by extensive activities of man; biological production not too forced. Native species altered, occasionally managed. Little or no presence of constructions or artefacts. Little or no management of water cycle (passive)
[4]	Cultural assisted system; important infrastructures and/or conditioning of the physical environment; forced biological production; moderate addition of matter (usually with pollution associated). Natural elements intermixed, in patches or corridors. Active management of water
[3]	Highly intervened system: still areas with biological production (natural/cultivated/breeding) mixed (mosaic) with buildings and infrastructures. Natural biodiversity severely reduced; its elements rather isolated (intense fragmentation). Water dynamic manipulated. Geomorphology usually altered; soils eventually removed
[2]	Semi-transformed system; biological production not dominant, disarticulated. Predominance of constructed elements. Occasional moderate vertical development of facilities. Intensive input of energy and matter (food, water) from the outside. Intensive control of water
[1]	Transformed system; anthropic processes governing; clear dominance of articial elements; frequent intensive vertical development; vestiges of natural elements; those exotic confined, decorative or not visible. Full dependence of external inputs of matter and energy. Absolute control of waters
[0]	Articial system; high closure; without self-maintained macroscopic life; microscopic life absent or in containers

Fig. 2. Map of naturalness of vegetation on the Canary island of Hierro (after Machado 2008).

contexts suggested the year presumed vegetation condition in year 1750, the benchmark year of European settlement in Australia. According to Oliver et al. (2002) this work guided the development of the National Framework for Assessing Vegetation Conditions of the National Land and Water Resources Audit (Environment Australia 2000, 2001). The 1750 suggestion has been later misused by Ferrari et al. (2008) who applied as criterion in their "naturalness" scale designed for Europe (sic!). It has also need heavily criticised by Oliver et al. (2002) who listed five objections against its use as benchmark. Oliver et al. (2002) argued that the adoption of 1750 model

1) will likely lead to inaccurate estimates for geographically restricted or heavily degraded, cleared and fragmented vegetation types;
2) may lead to devaluating (from biodiversity conservation point of view) of native vegetation that differs in type from that predicted (reconstructed rather) for on-site conditions prior to 1750;
3) may lead to attempts to restore a modelled vegetation type to what may now be unsuitable location due to significant irreversible changes in role of ecological drivers,
4) maybe not be appropriate because of its philosophical complexity (see Peterken 1981); and finally
5) might not be necessarily consistent with the most effective biodiversity conservation outcomes in highly modified landscapes since the naturalness concepts were developed for application to large concepts.

I would add that having proper modelling tools and proper data in hands, it is possible to produce reasonable (acceptable and scientifically plausible) model of reconstructed vegetation (see Neuhäusl 1963, Mikyška et al. 1968, ESCAVI (1990). However, although these models may well reflect the past of zonal (sensu Walter 1976, Walter & Box 1976) vegetation (large-scale patterns for the sake of simplicity), they fail miserably in reconstructing azonal vegetation (vegetation of special, usually very small-scale habitats such as salt pans, estuaries, temporary pools and freshwater wetland sin general, vegetation of rocky outcrops and coastal cliffs. Undoubtedly these unique vegetation types are under pressure of change, house considerable portion of biodiversity, endemic species and unique communities – hence deserve to be monitored and cared for.

I tend to concur with Oliver et al. (2002) that if to use benchmarks at all, than using current native vegetation types rather than that what might have existed on the locality (but often not in the same habitat!) is a more defendable option.

Hemeroby as well as 10-degree system by Loidi (1994) use *potential natural vegetation* (PNV) as the reference condition. PNV (originally coined by Tüxen 1956) is defined by Kowarik (1987) as "a hypothetical (potential) most developed vegetation, corresponding to the present (not future) site conditions". Recent critical appraisal, historical account of the PNV concept, accompanied by numerous literature sources, is found in Mucina (2010). Use of PNV as benchmark is highly contentious because of the hypothetical nature of the PNV. Machado (2004) further criticised the link between naturalness and a climax (=PNV in his understanding) because natural disturbance may revert (in other words "rejuvenate") the directional vegetation changes to stages which should be equally considered "natural". Use of "mature vegetation phase" as benchmark of naturalness systems (see Blasi et al. 2001, 2003, Guarino et al. 2008) roots in ill-conceived notion that more complex (forest) communities are more "mature" (what ever maturity would be standing for?) than vegetation of non-forest vegetation. This wrong perception invokes ghosts of mono-climax past (see Tansley 1935) and even more spooky times when the theory of "sociological progression" (Braun-Blanquet 1964, Böttcher 1980) was till alive. According to this idea, vegetation types can be ordered into a linear classification system according to the state of "maturation" of vegetation.

Schafale & Weakly (1990) defined accordingly the potential natural condition, the conditions that would prevail if humanity and all its works were removed from the earth, all exotic species eliminated, and recovery processes allowed to occur without climatic or geologic changes.

Interestingly, in some parts of the world not only natural, but also anthropogenic (man-made) ecosystems became subject of conservation. For instance the dramatic change of land use (abandonment of traditional crops, cleaning of settlements) resulted in decline of "traditional" anthropogenic plant communities. In some countries these vanishing anthropogenic vegetation was either put on the red lists (Jedicke 1997) or became subject of active conservation and even reconstruction (see further literature in Mucina 1989).

Subjectivity of Assessment

The process of assessment of hemeroby (naturalness and related) is marred by numerous poorly defined steps reflecting high level of subjectivity. Although I appreciate that subjectivity of assessment in science is a daily practise (Annett 2002), much of the controversy can be mitigated by converging expert opinion, for instance by using so called Delphi Method. Still, the hemeroby/naturalness assessment in ecology still made little effort to place the assessment on firmer operational ground.

The "normal" assessment of this kind usually traces the following procedure:

1) selection of the assessment object (e.g. vegetation stand, vegetation map of a region, habitat patches in landscape etc.);
2) selection of an assessment scheme fitting the aim (e.g. naturalness scheme for forests, hemeroby scale to judge level of synanthropization of vegetation patch etc.);
3) assignment of the object into a degree at the hemeroby/naturalization scale used (following criteria characterizing each degree);
4) in case of vegetation map available, assignment of each polygon to hemeroby/naturalness degree and hence mapping of the hemeroby/naturalness.

The usual problems emerge first at the level of Step 2 since several unique schemes (featuring various level of detail) are available (see Fig. 3).

Grabherr et al. 1997, 1998	Hornstein 1950	Dierschke 1984	Ellenberg 1963	**Examples from forests** (following Grabherr et al. 1998, modified)
9 (ahemerob)	Natural forest community	Natural	Virgin	Forests **untouched** by man, inaccessible sites; or previous impact completely historic; e.g., spruce forests and Pinus mugo-"Krummholz" on steep slopes in the Alps
8 (γ-oligohemerob)			Natural	
7 (β-oligohemerob)		Near-natural	Near-natural ("naturnah")	Forests **with irregular, weak, selective use**; near-natural tree species composition; only minor modifications of ground vegetation and stand strucutres; absence of old stand phases ("decaying stage"); e.g., some spruce forests in the Alps.
6 (α- oligohemerob)	Seminatural managed forest		Relatively near-natural	
5 (β-mesohemerob)		Semi-natural	Relatively unnatural ("naturfern")	**Moderately modified** forests. Dominant and subdominant tree species of the potential natural vegetation occur, but with shifted proportions due to management (harvesting of trees, wood pasture). E.g., beech-fir-forests with >50 % spruce in the Alps
4 (α-mesohemerob)	Relatively unnatural managed forest ("naturferne Waldbautypen")	Relatively unnatural ("Naturfern")		**Strongly modified, intensively used** forests with simple stand structure (evenaged forests); tree species of pnV only minor canopy component. In the ground vegetation, many species from openland (ruderals, weeds) can be found, or even complete absence of ground vegetation due to lack of light. Example: stand with canopy formed by spruce or even exotic species (only few deciduous native species) in beech climate.
3 (β-euhemerob)			Relatively unnatural ("naturfern")	
2 (α-euhemerob)	Not natural managed forest	Artificial („künstlich")	Not natural	"Artificial" (evenaged) forest of planted tree species not native to that site; in field-layer ruderals and weed species predominate, forest species are rare. Example: Afforestation with conifers (in beech climate)
1 (polyhemerob)	Artificial forest		Artificial ("künstlich")	

Fig. 3. Comparison of selected scale of hemeroby and naturalness (from Reif & Walentowski 2008).

The next, more serious, problem emerges at Step 3. The degrees of the most of the known hemeroby/naturalness schemes as only verbally defined, offering a fuzzy definition which might not be interpreted unequivocally or very complicated and often obfuscated assessment schemes. The assignment of assessed object into a hemeroby category based on complex verbal definition is acceptable however more experiments such as those performed by Gorrod & Keith (2009) and calibrations (for a promising approach see Czúcz et al. 2008, 2010) are needed. Some of the definitions of degrees as fully meaningless, as exemplified by the degree *DE (natural)* in Ferrari et al. (2008), which read: "vegetation with minimal influence by man; this degree contains vegetation close to the pre-1750 condition and vegetation belonging to naturally stressed and disturbed habitats (e.g. vegetation of saline and sand habitats)." Authors here obviously overlooked that 1750 benchmark (Hopkins 1999) separated the pre-European and post-European period in the history of colonization of Australia by European settlers, while they applied their "degree of naturalness" system to vegetation of Northern Apennines (Italy)!

Some of the schemes (such as for instance that of Schirmer 1999 or of BMVEL 2004) are more explicit since their criteria are simple, based on % share native/alien plant species. Naturally, in the latter case another problem emerges – the validity of using only native/alien ratio to express naturalness or level of degradation of vegetation. One can easily find heavily impacted forest (destroyed structure, loosing native species) and yet, no alien species invading the vegetation.

Additional source of serious problem rests (e.g. Kim & Lee 1997, Guarino et al. 2008, Ferrari et al. 2008) in construction of summarizing indices based on hemeroby or naturalness degrees. Many hemeroby and naturalness systems pretend to have shape of (at least) *ordinal* scales. This is an illusion and amount to self-cheating since these scale are in fact nearly invariably *nominal* scales. This misconceptions leads to submission of the numerical (or replacement) values to meaningless statistical calculations, such as addition and multiplication of "values" based on nominal data (see Stevens 1946 for permitted arithmetic operations and Wolman 2006 for discussion).

2.2 VAST & ACT Assessment: Aussie Versions of Hemeroby Assessment

2.2.1 Principles and Limitations of VAST

VAST assessment (standing for "Vegetation Assets, States and Transitions"), coined by Thackway & Lesslie (2005 and later), clearly falls within the hemeroby/naturalness family of assessment frameworks. Yet it deserves a special attention of this Report since it was design to assist in country-wide assessment of vegetation condition of Australia. Obviously it is an attempt to cope with major headache of all VC assessments – the trade-off between detail and generality, to accommodate both simplicity of data acquisition and complexity of huge area such as Australian continent.

VAST framework entails ordering vegetation by degree of anthropogenic modification as a series of condition states, from a residual or base-line condition through to total removal (Thackway & Lesslie 2008). A benchmark is identified for each vegetation association based on structure, composition and current regenerative capacity. VAST consists of seven condition states, of which States I through III (Residual, Modified, Transformed, resp.) pertain to Native Vegetation Cover, the States IV through VI (Replaced-Adventive, Replaced-Managed, removed) pertain to Non-native Vegetation Cover) and State 0 designates Naturally Bare area (Fig. 4). VAST uses (the same way as hemeroby or many naturalness schemes, see above) a benchmark. Relative change in condition from this benchmark is assessed for each site or patch (Thackway & Lesslie 2006). The nature of the benchmark is based on the best understanding of pre-European (pre-1750) conditions and can relate to a single reference site, or can be defined as a an "average" (or range) of in values for a set of reference sites (Thackway & Lesslie 2006, Hnatiuk et al. 2009). In VAST the State I serves as

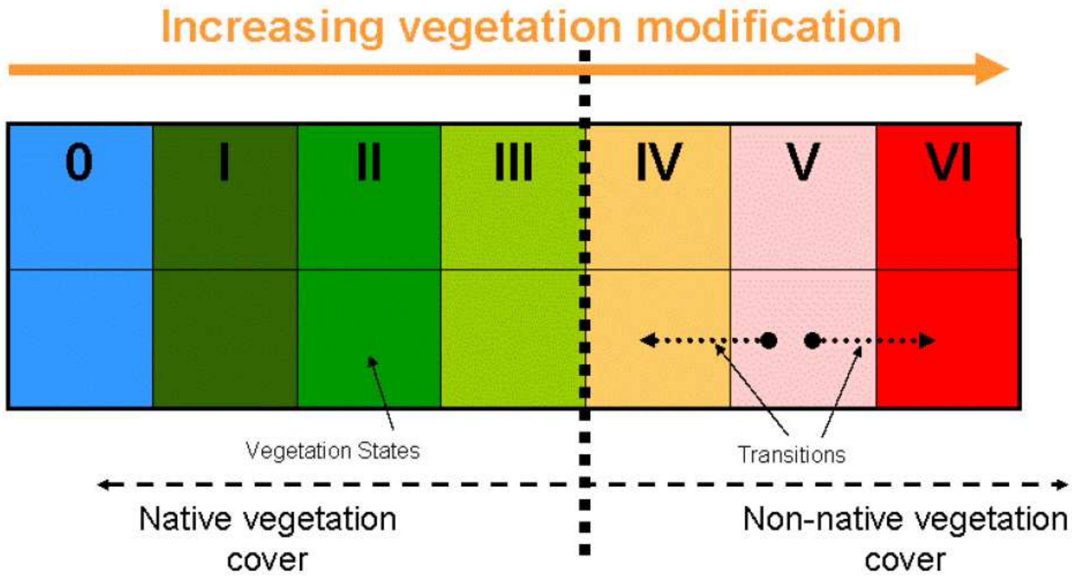


Fig. 4. The categories of the VAST conceptual framework (from Thackway & Lesslie 2005).

the benchmark. Three main diagnostic criteria, such as floristic composition, vegetation structure, and regeneration capacity underpin the VAST network (see Fig. 5).

The application of VAST rests on the seven guiding principles (Thackway & Lesslie 2008). The wording of these principles is based on the latter source, but has been shortened for the most part, further edited, and extensively commented on in the sequel:

1. The existing seven states can be further (depending on further requirement) subdivided into substrates.
Comment: VAST framework is linear at the moment, but can be redesigned to accommodate nested hierarchical structure.

2. Natural non-vegetated states and substrates are bare areas. In the context of the NVIS framework (ESCAVI 2003), naturally non-vegetated ‘‘definitive vegetation types’’ (Hnatiuk et al. 2009) could be included in state 0 (e.g., salt lakes, sand, mud flats, and rock).
Comment: Technically, bare substrate should NOT count as "vegetation" and "naturally non-vegetated definitive vegetation types" are an oxymoron. Inclusion of State 0 into the VAST framework is unfortunate and it should be out of bounds of the framework. Bare ground is NOT a state of vegetation.

3. Condition assessments can be reported at different points in time for the same area using structural, compositional, and functional attributes. To enable such

Increasing vegetation modification from left to right

		Native Vegetation Cover Dominant structuring plant species indigenous to the locality and spontaneous in occurrence – i.e. a vegetation community described using definitive vegetation types relative to estimated pre1750 types[#]				Non-native Vegetation Cover Dominant structuring plant species indigenous to the locality but cultivated; alien to the locality and cultivated; or alien to the locality and spontaneous*		
Vegetation Cover Classes		Type 0: RESIDUAL BARE Areas where native vegetation does not naturally persist	Type I: RESIDUAL native vegetation community structure, composition, and regenerative capacity intact – no significant perturbation from land use/land management practice	Type II: MODIFIED native vegetation community structure, composition and regenerative capacity intact - perturbed by land use/land management practice	Type III: TRANSFORMED native vegetation community structure, composition and regenerative capacity significantly altered by land use/land management practice	Type IV: REPLACED - *ADVENTIVE* native vegetation replacement – species alien to the locality and spontaneous in occurrence	Type V: REPLACED - *MANAGED* native vegetation replacement with cultivated vegetation	Type VI: REMOVED vegetation removal
Diagnostic criteria	Current regenerative capacity	Natural regenerative capacity unmodified - ephemerals and lower plants	Natural regenerative capacity unmodified	Natural regeneration tolerates / endures under past &/or current land management practices	Natural regenerative capacity limited / at risk under past &/or current land use or land management practices. Rehabilitation and restoration possible through modified land management practice	Regeneration of native vegetation community has been suppressed by ongoing disturbances of the natural regenerative capacity. Limited potential for restoration.	Regeneration of native vegetation community lost or suppressed by intensive land management. Limited potential for restoration	Nil or minimal
	Vegetation structure	Nil or minimal	Structural integrity of native vegetation community is very high	Structure is predominantly altered but intact e.g. a layer / strata and/or growth forms and/or age classes removed	Dominant structuring species of native vegetation community significantly altered e.g. a layer / strata frequently & repeatedly removed	Dominant structuring species of native vegetation community removed or predominantly cleared or extremely degraded	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
	Vegetation composition	Nil or minimal	Compositional integrity of native vegetation community is very high	Composition of native vegetation community is altered but intact	Dominant structuring species present - species dominance significantly altered	Dominant structuring species of native vegetation community removed	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
Examples		Bare mud; rock; river and beach sand, salt and freshwater lakes	Old growth forests; Native grasslands that have not been grazed; Wildfire in native forests and woodlands of a natural frequency and/or intensity;	Native vegetation types managed using sustainable grazing systems; Selective timber harvesting practices; Severely burnt (wildfire) native forests and woodlands not of a natural frequency and/or intensity	Intensive native forestry practices; Heavily grazed native grasslands and grassy woodlands; Obvious thinning of trees for pasture production; Weedy native remnant patches; Degraded roadside reserves; Degraded coastal dune systems; Heavily grazed riparian vegetation	Severe invasions of introduced weeds; Invasive native woody species found outside their normal range; Isolated native trees/shrubs/grass species in the above examples	Forest plantations; Horticulture; Tree cropping; Orchards; Reclaimed mine sites; Environmental and amenity plantings; Improved pastures. (includes heavy thinning of trees for pasture); Cropping; Isolated native trees/ shrubs/ grass species in the above examples	Water impoundments; Urban and industrial landscapes; quarries and mines; Transport infrastructure; salt scalded areas

Fig. 5. Elements of the conceptual framework of VAST assessment (from Thackway & Lesslie 2005).

comparisons to be made, it is necessary to collect and compare the same diagnostic attributes to assess changes in the condition state of particular vegetation associations and their extent in different parts of the landscape (original wording by Thackway & Lesslie 2008).

Comment: Ability to use VAST to report repeatedly (in monitoring style) about status of structural, compositional and functional attributes would be ideal. This should be actually the most important goal of any vegetation assessment: to report on condition at selected "points" along the time axis to be able to depict trends. The simplistic nature of the VAST assessment would inevitable result in serious deviations in interpretation of the criteria during the repeated assessments (presumably done by various field researchers) which would preclude unbiased repeated reporting. Translation of the VAST assessment into spatial terms (mapping) would need selection of representative sites and/or transects.

4. Native vegetation refers to those condition states and substrates that can be defined and mapped where the regeneration of species/communities and ecosystems is not predominately prevented or excluded by land management practices. Because native vegetation can be identified by characteristics of its structure and composition (Hnatiuk et al. 2009), it provides a distinctive, but not exclusive, set of attributes that can be surveyed and mapped or monitored (original wording by Thackway & Lesslie 2008).

Comment: This "principle" described the nature of native vegetation. It appears (from Figs. 4 and 5 and the comparisons between the principle 4 and 5) that the distinction between "native vegetation" and "non-native vegetation rest on very contentious and highly speculative notion of "regeneration potential": regeneration of native vegetation is not hindered, while the regeneration in non-native vegetation is hindered to return to native status. This principle reveals that *the authors of VAST presume automatic regeneration of non-native (vegetation, at least State IV) into native, while at the setting of the benchmark in VAST framework relies on understanding of pre-European vegetation. There is no guarantee that pre-European vegetation would recover once the current “land management and practices” would be excluded. Logical controversy surrounding the definition of native and non-native vegetation (in relation to the benchmark) needs serious rethinking.*

5. Non-native vegetation includes those condition states and substates where the vegetative cover is predominately non-native and regeneration of the native vegetation is repeatedly suppressed or prevented by land management practices. Such areas include VAST V (e.g., crops, plantations, and improved pasture) and VAST VI (areas where the vegetation has been removed, e.g., water reservoirs, urban areas, salt crusted areas, and tilled bare soil) (original wording by Thackway & Lesslie 2008).
Comment: See my comment on Principle 4.

6. In the context of point 3 above, where condition states can be defined and mapped across the whole landscape, management actions can be used to facilitate transitions between condition states. In the short to medium term it is not possible to ‘‘transition’’ a non-native condition state (i.e., States IV–VI) back to a native condition state. Where stakeholders plan to restore areas that were formally non-native vegetation types with native species, the structure, composition and function and the regenerative capacity of the ‘‘reconstructed native vegetation’’ will (in the short to medium terms) be discernable as a revegetated type. For the purposes of reporting, such revegetated areas should be denoted as VAST State V.
Comment: The above statement implies that it is not possible to reconstruct vegetation to achieve status which might texturally (floristic composition), structurally (vertical layering and horizontal patchiness), and functionally (reconstruction of basic ecosystem services) remind (mimic) natural status. This actually amounts to the modern restoration ecology that they are looking for Holy Grail or doing Tantal’s work. I think that this reveals a major weakness of the VAST system: failure to provide for condition states which cannot be classified as “native” (because of no piece of transformed vegetation would ever be able to match pre-1750 condition), but still will be having natural appearance and performing natural functions.

7. Datasets that are eligible for translation and/or interpretation into the VAST framework must have implicit or explicit benchmarks (Thackway & Lesslie 2006) for each vegetation association.
Comment: This is a logical requirement, since the benchmark might aid “translation” of different assessment systems into VAST. However, more effort has to be invested in at least solve problems of: (a) matching of the benchmarks used in different assessment systems, and (b) the effect of subjective definition of “vegetation association”.

In summary, I believe that VAST (alongside with other, perhaps more sophisticated approaches such as hemeroby) can be seen as a promising step towards vegetation condition assessment for large regions. Yes the benchmark setting criteria and consequently some of the Principles need thorough revisiting. The biggest challenge to solve is to make VAST liable to repeated assessments (including monitoring and fast data-collection using remote-sensing). At this stage it is obvious (see Hnatiuk et al. 2009) that VAST has not been accepted (or suggested) as the nation-wide vegetation assessment framework.

2.2.2 Mapping VAST Assessment

Thackway & Lesslie (2008) documented the use of their VAST system by compilation of a series of local, regional and national datasets which were then used to map the VAST assessment. They involved an implicit pre-European benchmark vegetation condition for each vegetation association and collated knowledge of the effects of land use and land management practices upon the integrity of the native vegetation in a 1-km grid cell. Here (Fig. 6) I reproduce their nation-wide map of VAST as an example. This map comprises information collected between 1995 and 2003 and the key inputs were derived from the Biophysical Naturalness layer within the Australian Land Disturbance Database (ALDD), a national land use dataset prepared for the National Land and Water Resources Audit, a variety of catchment scale land use datasets produced through the Australian Collaborative Land Use Mapping Program and MODIS satellite imagery (for details and references see Thackway & Lesslie 2008). GIS methods were used to overlay input datasets and the VAST states in each dataset were averaged to derive a synthetic VAST condition state for each grid cell. The latter procedure involved averaging of values representing nominal data, which violates the assumptions of use of measurement scales (Stevens 1946).

Comparing the nation-wide VAST mapping with some of the regional-scale VAST datasets, Thackway & Lesslie (2008) were able to detect obvious differences which highlight the need to understand issues of accuracy and precision as well as levels of detail associated with the scale of mapping or modeling and the need for consistency between the attributes used to derive the mapped condition state datasets.

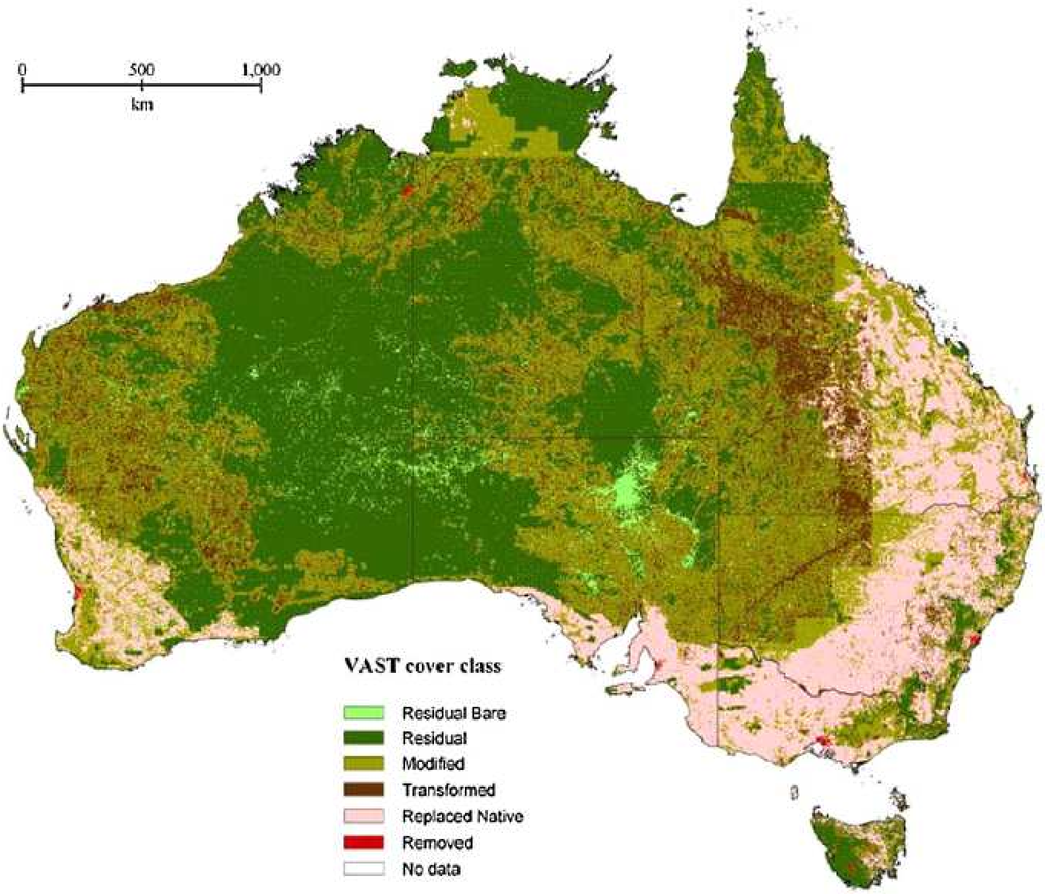


Fig. 6. Preliminary VAST assessment map of the Commonwealth of Australia (from Thackway & Lesslie 2008).

2.2.3 ACT Grassland Assessment

The ACT (Australian Commonwealth Territory) protocol for vegetation condition rating (ACT Government 2004, 2005, Sharp 2006) is based on so called *Botanical Significance Rating (BSR)* considering the cover, richness and rarity of plant species or, and on an assessment of *vegetation structure* of a survey unit. The rating is applied to polygons (survey units that are homogenous in terms of plant composition and structure (Sharp 2006). These two criteria then (to me in not quite transparent manner) aid assignment of a vegetation patch (polygon) into one of 5 possible vegetation condition ratings (1: Unmodified and grassy vegetation; 2: Partially modified vegetation; 3: Moderately modified vegetation; 4: Highly modified grasslands; 5: Substantially and severely modified vegetation).

2.3 Favourable Conservation Status: European Union Approach

European Union EU) is one of the world's economic (and otherwise) superpowers, incorporating 25 member states maintaining their political and cultural identity, while showing high level of integration at levels of finances, economics, defence, foreign politics and last but not least in culture. Nature conservation has always been a national (and often parochial) matter, however EU had made important steps towards setting common EU-wide goals and provided political and legal instruments to coordinate nature conservation and management fitting the unifying structures of the EU legislature and economics.

Council of European Communities has issued on 21 May, 1992 the ***Directive 92/43/EEC on The Conservation of Natural Habitats and of Wild Fauna and Flora***, which under the short name "Habitats Directive" (further HD) became the key instrument for biodiversity conservation in the EU. Its main aim is stated to be ***"to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements"*** (Preamble of the Habitat Directive). The HD provides, among many other things, for the designation of special areas of conservation and thus creating a coherent European ecological network which came known as "Natura 2000". In the HD, maintenance or restoration of natural habitats and populations of wild species of the Community interest at a ***favourable conservation status (FCS)*** is defined as an overall objective of conservation measures (Mehtälä & Vuorisalo 2007).

In summarizing words (see for instance Mehtälä & Vuorisalo 2007, Zingstra et al. 2009; see also Tab. 5**)**, the conservation status of a habitat type shall be considered as being "favourable" when:

- its natural range and areas it covers within that range are stable or increasing, *and*
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, *and*
- the conservation status of its typical species is favourable as defined below in the description of the conservation status of the species.

As these criteria are obviously too broad to be applied in operational way especially for reporting purposes, the Commission of the European Communities (CEC) attempted development a set of more detailed criteria of the assessment (in form of an evaluation matrix; for final report see Commission of the European Communities 2004). Reporting on the status if the conservation network (anchored in Art. 17 of HD) by the Member States Crucial, has been the major motivation for the development of the evaluation matrix. It appears that the criteria set by CEC are only a guideline, followed by the Member States to a certain degree, still leaving space for idiosyncratic national views (see for instance Ellmauer 2005 for Austria, Søgaard et al. 2007 for Denmark, Šeffer et al. 2005 for Slovakia, Zingstra et al. 2009 for Bulgaria etc.). In the Danish report on the criteria of national FCS assessment, Søgaard et al. (2007) suggested that the more specific, precise criteria should meet the following requirements:

Tab. 5. Ecological interpretation of the criteria of the Favourable Conditions Status (after Mehtälä & Vourisalo 2007).

Habitats: 1. Stable or increasing natural range	*How to identify habitat types?*	Organizing comprehensive national habitat monitoring networks.
2. Long-term persistence of specific structure and functions	*What are specific structures and functions?* *How much diversity is required to maintain specific structures and functions?* *Do species substitutions affect specific structures and functions?*	Comparative ecosystem studies; organizing comprehensive monitoring networks for selected habitat structures and functions.
3. Favourable conservation status of typical species of the habitat	*What are 'typical' species?* *How large a habitat area is required to maintain a characteristic species pool?*	Organizing comprehensive national monitoring networks for keystone or 'charismatic' species.

- They should be able to form the basis for monitoring the conservation status of the habitat type or the species;
- They should be biologically relevant, and provide a basis for the protection of nature;
- They should be immediately intelligible, and based on professionally reasonable simplifications;
- The monitoring methods should be operational, and repeatable; and
- They should be quantifiable.

Tabs. 6 and 7 bring examples of these more detailed national criteria and their application, respectively, to one of the habitat types registered by the Annex III of the HD (Søgaard et al. 2007).

The EU framework for FCS assessment includes four categories, such as ***favourable, unfavourable-inadequate, unfavourable-bad, unknown***. Because the first three categories are being colour-coded as green, amber, and red, respectively (CEC 2004), this system is also dubbed "Traffic Light System" (see Fig. 7).

Using their own national criteria (still within the set framework given by the CEC 2004 and later), the EU has compiled in July 2009 (CEC 2009) the first ever systematic assessment of the conservation status of Europe's most vulnerable habitat types across all 25 Member States and 11 (seven land and four marine) bio-geographical regions. The scale of this reporting exercise is unparalleled in Europe and has provided a first overview and point of reference for assessing future trends. This report is based on the report issued by European Topic Centre on Biological Diversity (2008) for the DG Environment of the CEC (see http://biodiversity.eionet.europa.eu/article17). Fig. 8 presents one of the map

Tab. 6. Danish national criteria of favourable condition status (after Søgaard et al. 2007).

NATIONAL	Property	Unit of measurement	Criteria	Comments
Area and natural range	Area	Number of hectares	Stable or increasing in relation to the level laid down	Minor losses of area, due to natural succession or dynamism, including factors such as coastal erosion, may be accepted.
	The range of the habitat type	Number of occurrences and number of hectares in each province within the natural range of the habitat type.	Stable or increasing	
Structure and function	Area with favourable conservation status *	Hectare	Stable or increasing compared to the level laid down	Ought not to be less than 70-75% of the mapped area in the habitat areas. Requires developmental work.
Characteristic species	Population of each characteristic species	Number of occurrences per species, and overall index of frequency	Stable or increasing	The species should be considered to be able to maintain current levels as a viable component of its natural habitats on a long-term basis, on the basis of data from at least two consecutive monitoring periods.
	The range of the characteristic species	The number of provinces with occurrences of the characteristic species	Stable or increasing	

* Found by adding together the total area with favourable conservation status on a site level

products of an EU-wide FCS assessment (synthesized on basis of various national reports) of a listed habitat type from the latter source.

Mehtälä & Vuorisalo (2007) recognised several problems and challenges with FCS when used to assess the status of habitats (hence vegetation in most cases) and listed: (1) obvious lack of historical data, hence difficulty to set references/benchmarks, (2) problems with the unequivocal identification habitats, (3) problems with identification of habitat-specific structures and functions, and (4) obvious problems of scale faced when national (often idiosyncratic) assessment are supposed to be collated into an pan-EU picture.

FCS can be applied to assess vegetation condition in principle in the same ways as any class-based approach (hemeroby, naturalness, VAST) and does suffer from similar ailments. Use of *thresholds* in definition of some of the categories, makes it however more attractive form the point of view of equivocality of the assessment. Attempts to calculate all sorts of "synthetic values" based on FCS assessments (e.g. Šeffer et al. 2005), without considering the nature of the measurement scales and the permissible arithmetic operations, are a futile exercise.

Tab. 7. Criteria of favourable conservation status on a local/site level for habitat type 1330 in Denmark. Indicator marked P are pressure indicators (after Søgaard et al. 2007).

Type 1330	Property	Unit of measurement	Criteria	Comments
Area	**Area (hectares)**	**Number of hectares**	**Stable or increasing**	
Structure and function	Natural nutrient level	Nitrogen deposition (kg/N/hectare/year)	Not exceeding the critical load	The critical load 30-40 kg N/Hectare/year, UNECE 2003.
	(P) Hydrology	Proportion of area exposed to flooding from the sea	Stable or increasing	The ideal is natural hydrological processes with tidal creeks, beach ridges, landlocked lagoons, and salt pans. Sea walls, drains and ditches obstruct these processes.
	Acidity	pH	The pH must be stable and not considerably lower than the natural acidity of the locality.	If no historical information is available, the natural pH can be predicted by modelling.
	Conductivity	Conductivity (microsiemens)	Within the natural range for the habitat type in Denmark. Stable or improving.	Conductivity expresses the total ion capacity and is thus an important indicator for eutrophication.
	(P) Natural environment factors	Distance (m) to nearest area with pesticide and fertiliser application.	Stable or increasing	Should follow the current recommendations (minimum 50 m).
	Balance between low- and tall-growing species	Proportion of area with intense grazing/mowing.	Stable or increasing, although areas with extensive grazing should not be excluded.	Areas with extensive grazing and tall species may be valuable.
	Species composition of plants	Deviation from the species composition of this habitat type in the reference condition.	The deviation is within the natural variation of the habitat in Denmark.	The species composition is a strong indicator of changes in the environment.
Characteristic species	Population of characteristic species	Index of populations of characteristic species present	Long-term maintenance on a stable or increasing level	Register by species, e.g. using the DAFOR scale. Variations are natural. In special cases declines may be acceptable/targeted.

2.4 Mapping Dynamic Tendencies: Białowieża-Camerino Approach

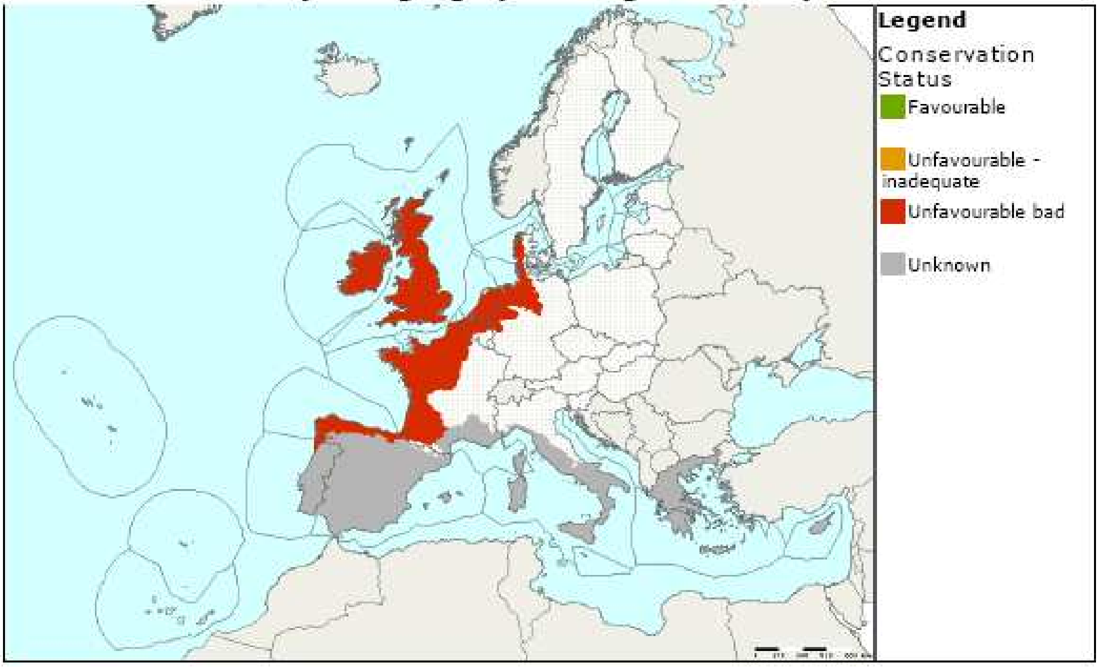
This approach is an odd ball within the VC assessment since it attempts uses to map information on “succession” status of the studied vegetation.

Janusz Bogdan Faliński (1934-2004), eminent Polish vegetation ecologist has formulated a piece of theory on nature of vegetation processes (at level of vegetation stands/habitats) rooted in classical theory of vegetation succession and incorporating elements of nature of population dynamic processes. The roots of the approach reach to the notion of “degeneration” of plant communities (Mráz 1950, Faliński 1966b, c, Olaszek 1972) and at least one publication (Faliński

Habitats Directive Article 17 Reporting European Environment Agency

Habitat code:**9330**
Habitat name: **Quercus suber forests**
Habitat group: **forests**
Regions: **ATL MED**

Assessments of conservation status at the European level (all biogeographical regions - EU25)



MS	Biogeographic Region	Conservation status assessment					Km^2	Trend in area
		Range	Area	Structure & function	Future prospects	Overall		
EU25	ATL						>1	-
EU25	MED						>2984	

Fig. 8. Example of report summary sheet featuring the favourable conservation status of the European habitat 9330 *Quercus suber* forests (from http://biodiversity.eionet.europa.eu/article17).

1966b) contains also a map showing various degeneration stages of vegetation. Faliński (1986b, c) distinguished *succession*, *regression* (both classified as directional dynamic processes), *fluctuation*, *degeneration/regeneration* (both considered fluctuation dynamic processes), and *seasonality* (considered cyclical dynamic process) as major dynamic (short- to mid-term) processes in vegetation. Further he incorporated classical conceptual dichotomy of **primary** from **secondary** succession, and further distinguished a number of effects within both primary and secondary successions (e.g. within the latter these were: *creative*

Table 3 — Fluctuation (units) and degeneration (consecutive phases) mapped in the vegetation of Bosco Quarto. Source: orig. elab. of JBF & FP.

FLUCTUATION

Fa	Fluctuation in the natural forest communities
Fb	Fluctuation in the seminatural brushwood communities
Fc	Fluctuation in the anthropogenic non-forest communities

DEGENERATION

Phases	
Phase 0	- Stable, natural or nearly natural forest community with well preserved structure and proper species composition
Phase 1	- Natural or nearly natural forest community with well preserved vertical structure, with patches of nitrophilous indicators of grazing *(Alliaria petiolata, Chaerophyllum temulum, Galium aparine)*
Phase 2	- Forest community with well preserved treestand; herb layer changed due to spreading grassland species (cespitisation)
Phase 3	- Forest community with well preserved treestand. Beside grasses, single specimens of *Asphodelus microcarpus* present in herb layer
Phase 4	- Forest community (dominated by *Quercus cerris*) with simplified vertical structure and impoverished species composition. In herb layer, *Asphodelus microcarpus* spreads in place of forest species
Phase 5	- Forest community (dominated by *Quercus cerris*), with simplified vertical structure. *Ilex aquifolium* present in shrub layer
Phase 6	- Forest community (dominated by *Quercus cerris*), with simplified vertical structure and impoverished species composition. Dense shrub layer with dominating *Ilex aquifolium* restrains the growth of herbs
Phase 7	- Forest community transformed into brushwood associated with grassland communities on rocks (oak/ash coppices; brushwood-grassland complex)

Table 4 — Regression consecutive phases mapped in the vegetation of Bosco Quarto. Source: orig. elab. of JBF & FP.

REGRESSION

Phases	
Phase 0	- Stable, natural forest community with well preserved structure and proper species composition
Phase 1	- Stable, natural forest community with thinned treestand and small clearings on shallow soil or on uncovered rocks
Phase 2	- Stable, natural forest community with thinned treestand and patches of heliophilous plants on small clearings
Phase 3	- Stable forest community with changes in the shrubs layer; treestand renewal restrained by grazing; patches of heliophilous plants in the herbs layer increase in size
Phase 4	- Forest community with looser structure; grassland species penetrate into forest; clearings increase in size; macroforb communities initiate on the border between forest and clearing
Phase 5	- Formation of grassland in place of the forest; changes in the tree habits (trees with rachis shoot bitten off and numerous offshoots formed at the base)
Phase 6	- Merging of patches of grasslands from the neighbouring clearings; the clearings are separated by small groups of trees with bushy offshoots, surrounded by macroforb communities
Phase 7	- Disappearance of trees between clearings; small clearings merge into big glades; integration of treeless grassland; penetration of grassland and nitrophilous species into adjacent forest due to grazing
Phase 8	- Fragmentation of the grassland due to heavy grazing
[Phase 9]	- Patches of grasslands remain only in crevices in sharp-edged rocks [not expressed]
[Phase 10]	- Barren rock, no vegetation cover except for patches of cryptogamic plants; single vascular plants with thorny or spiky shoots and leaves [not expressed]

Fig. 9. Example of legend of a map of vegetation dynamic tendencies. For an example of the map see Fig. 10 below. (from Faliński & Pedrotti 1992a).

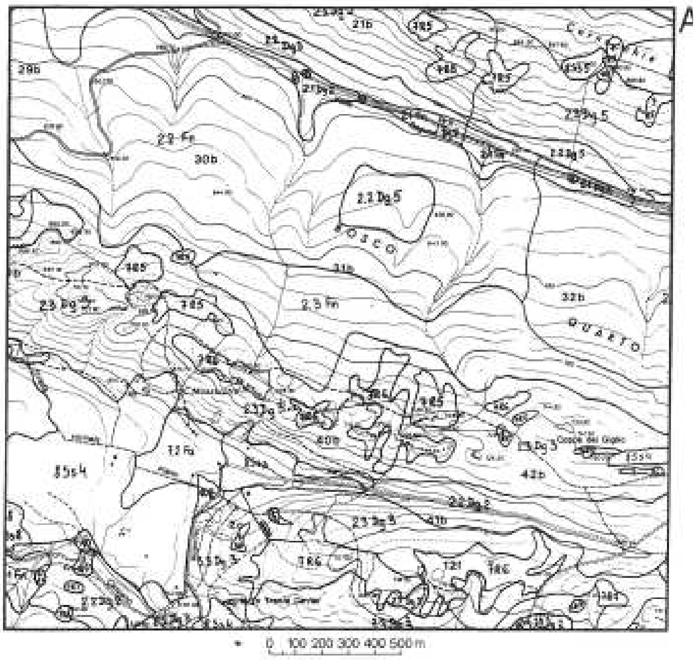


Fig. 10. Example of a map featuring vegetation dynamic tendencies (Bosco Quarto, Italy). For the legend to the mapping units see Fig. 9. (from Faliński & Pedrotti 1992a).

***secondary succession, replicative secondary succession, recreative secondary** succession*). Combination of these criteria would yield a mapping legend (depicting *phases*) such as depicted in Fig. 9. In the next step researcher has to establish the nature of vegetation dynamic processes in each distinguishable patch of vegetation and assign to which phase (corresponding obviously to a type of vegetation dynamic process) it belongs. An example of a resulting map id depicted in Fig. 10.

This theoretically innovative approach has, however, did not meet much appreciation outside the research group of J.B. Faliński located in Białowieża, Poland, and the research group lead by his close friend Franco Pedrotti of the University of Camerino. (Thence the nick-name of the approach: Białowieża-Camerino.) One notable exception is the paper by Emborg et al. (2000; see also Reif & Walentowski 2008).

The classical contributions of this approach include Faliński (1986a, b, c), Faliński & Pedrotti (1985, 1992a, b), Canullo & Pedrotti (1993). Theoretical accounts of the approach are found in Faliński (1986b, c, 1989, 1990-1991, 1991a, b) and in Pedrotti (2004). J.B. Faliński organised in 1990 an all IAVS symposium on “vegetation processes as subject of mapping”. The resulting volume (Faliński 1991c) contains number of papers addressing links between vegetation dynamics and mapping, but not pertinent to the aims of the Bialowieza-Camerino Approach.

The positive aspect of the Białowieża-Camerino Approach is the theoretical innovation and the honest effort to link vegetation dynamics and mapping of real vegetation. The major problem underlies the nature of definition of the mapping units. Firstly, the theory of vegetation dynamics is far from being in position offering unequivocal views of various types of vegetation-dynamical processes. Concepts such as succession, regression, degeneration are all very contentious, loaded with lot of subjective interpretation – hence theoretically far from being ripe to be understood and used in operational way. Secondly, the quest for knowledge vegetation dynamic status of each vegetation patch in a landscape is a life-time (if not longer) mission. The assignment of each patch to a "phase" is often very subjective (if not speculative), making the mapping of vegetation tendencies – a "modelling of speculation". Because of these uncertainties, this approach is not amenable monitoring (or repeatable and reliable) assessments.

3. Vegetation Condition Indices: In Quest for a Silver Bullet

This family of approaches to VC assessment sharing very similar traits, including (1) selection of assessment variables of very different quality (vegetation structure, species composition, characteristics of the habitat, etc.), (2) settling on estimation scales (usually either nominal, most commonly ordinal, and very rarely of ratio type), (3) assignment of a numerical value to each of the states, (4) weighting of the various variables, culminating into (5) calculation of a single summarizing value using usually complex indices.

In my "classification/ordination" analogy (see Section 2), this approach ordinates the position of the assessed object (e.g. vegetation patch) along a single ordination axis of VC, on a (usually) standardised scales of 0-1, 0-100 or more perhaps a little bit awkwardly between 0-75.

In fact most of the class-based approaches (such as hemeroby and naturalness), can also easily be translated into an ordination. Some of the class-based approaches also attempt translating of class indices (profile of hemeroby/naturalness classes) into a summary index. Examples of such attempts can be found in Kim & Lee (1997), Guarino et al. (2008), Ferrari et al. 2008 and Šeffer et al. (2005). The summary of the class values into a single-value index in all cited examples above is highly problematic as it neglects (in fact directly violates) basic rules of algorithmic calculus imposed by the nature of measurement scales (Stevens 1946, Wolman 2006; for more detail of this dangerous "cutting of corners" see the analysis of the Habitat Hectares approach below).

Four approaches to vegetation condition assessment were born and on the Australian East Coast. They all share basic goals and features (for details see below), and their contribution is of global importance. These approaches are:

1) Habitat Hectares assessment (State of Victoria 2002, Parkes et al. 2003, 2004, McCarthy et al. 2004, Gibbons & Freudenberger 2006, Michaels 2006, Newell et al. 2006a, b; see also theoretical and methodological build up in Oliver 2002, Oliver et al. 2002);
2) BioMetric assessment (Gibbons et al. 2005, 2008, 2009, Gibbons & Freudenberger 2006);
3) BioCondition assessment (Eyre et al. 2005, 2006, 2008).

Special issue of Ecological Management & Restoration (2006) has been devoted to these approaches. As they have also been reviewed elsewhere (see Bleby et al. 2008), I shall comment on those only in a general manner, mainly aimed at elucidating their position and importance on the global stage of vegetation condition research. I shall also provide some critical assessment of some aspect of the calculus of summary indices, not provide by Bleby et al. (2008).

All Australian East Coast VC assessment schemes belong to a family of index-oriented approaches (final assessment index is a major target) and all are based on set (more-or-less) relevant assessment criteria pertinent to biodiversity conservation. The Habitat Hectares (HH) approach seems aspiring for broader than original state-wide (Victoria) application (see Michaels 2006 for Tasmania). HH also served as major motivation of the discussion paper released by ESCAVI (2003) in attempt to reach general agreement across Australian Commonwealth states and territories to adopt a nationally consistent approach to vegetation condition assessment (see also Parkes & Lyon 2006). It is therefore not surprising that HH received some overseas interest (citations) and as it involves several contentious procedures, it became subject of discussion and open criticism. Some issues were addressed by McCarthy et al. 2006 and some are added in this report (see my Comments below each step).

The HH protocol involves the following Steps:

<u>Step 1: ***setting the object of assessment*** or identification of plant community for assessment</u>

Parkes et al. (2006) suggested using Ecological Vegetation Classes which are supposed to represent "represent aggregations of floristic communities with structural, physiognomic and floristic affinities that exist under a common regime of ecological processes within a particular environment (Woodgate et al. 1996, see also Parkes et al. 2003).

Comments: Parkes et al. (2003) admitted that it would be preferable to use floristic communities as the level for assessing vegetation type, however the proposed use of EVC was motivated by then more comprehensive coverage (in terms of vegetation mapping and description) across Victoria at the EVC level than the floristic community level. I maintain that of the VC assessment should serve the "biodiversity conservation context" (as also stated by Parkes et al. 2003) the floristic-based vegetation types should be subject to VC assessment in the first place.

Step 2: ***settling of benchmark*** for comparative purposes;

The HH approach is a relative assessment methodology and therefore setting of benchmark is vital. Parkes et al. (2003) suggest that benchmarks relate to a single EVC within one bioregion and account for some of the variation of a plant community across its natural range. HH approach uses a single value chosen from this range as the reference 'benchmark' point. Where possible, these benchmark values are generated from existing native vegetation known to be relatively undisturbed. Where this is not possible (poor condition of remaining examples of the vegetation type), benchmark values are devised to represent the presumed long-undisturbed condition of that EVC using historical information on previous disturbance regimes (Parkes et al. 2003).

Comment: Firstly, it is commendable that Parkes et al. (2003) refrained form using hypothetical pre-1750 vegetation as source of benchmarks. They have argued their case for not doing so quite well in Oliver et al. (2002). McCarthy et al. (2004) criticized their approach to selection of a single benchmark using "relatively undisturbed" vegetation patches rightly pointing out to the fact that (1) over the last 80 years, ecologists throughout the world have found it difficult to identify vegetation communities that have reached a climax or that move consistently to some prescribed ideal, and (2) they strongly felt that the role of disturbance was underestimated because single benchmark cannot accommodate appropriate disturbance regimes. In their response Parkes et al. (2004) dismissed the notion that their approach implies existence of "prescribed ideal" or "climax", and argued that the choice of mature and apparently long-undisturbed benchmark was intended to provide reference point that encompasses the full range of condition states. Parkes et al. (l.c.) further specified the interpretation of "mature" according to dominant growth form and reproductive strategies of the vegetation type. Firstly, the term "mature" remains highly contentious as it does reveal belief that that vegetation development is a sort of directional process of maturation, possibly becoming apparent through change of growth forms strongly invoking the notion of climax. Secondly, the statement on "reproductive strategies" is too cryptic to be able to see the relevance of "reproductive strategy" to selection of benchmark. Besides, vegetation types (theoretical constructs) do not have reproductive strategies – if somebody does, than plants do.

Step 3: ***selection of vegetation condition evaluation characteristics***

This step is the core of the methodology – it entails selection of evaluation criteria which are scored (mainly) on the site and which are supposed to depict various faces of the vegetation condition, relevant to biodiversity conservation. Parkes et al. (2003) suggested 10 habitat attributes made distinction between components of "site condition" and "landscape context" attributes (Tab. 8).

Comment: It is apparent that the choice of the habitat attributes was assisted by broad consultation process involving range of specialist botanists and ecologists (see also Oliver 2002) which lends the process of the selection certain level of seriousness. McCarthy et al. (2004) basically support the choice of attributes, but criticise some (especially those serving as surrogates) for lack of clarity of the relationship between the surrogate and intended measured variable. They also criticise some variable for being prone to considerable estimation errors as a result of variability of perception between

Tab. 8. Components (criteria/variable) and weightings of the scores of the Habitat Hectare approach. (from Parkes et al. 2006).

	Component	**Max. value (%)**
Site condition	Large trees	10
	Tree (canopy) cover	5
	Understorey (non-tree) strata	25
	Lack of weeds	15
	Recruitment	10
	Organic litter	5
	Logs	5
Landscape context	Patch size*	10
	Neighbourhood*	10
	Distance to core area*	5
	Total	**100**

*Components may be derived with assistance from maps and other (e.g. GIS) information sources.

assessors. My major concern is more general: It is fine that many experts do agree on importance of an attribute, still I miss proper ecological and evolutionary reasoning behind the choice of each of the variables. It should become clear (using proper documentation of the process) what is the direct relevance and what is the context of choice of an attribute to the target – biodiversity conservation. For instance what is the relevance of "large trees" in assessment of natural non-forest vegetation? Fair enough, some of the argumentation can be found (mainly between the lines) in Parkes et al. (2003; see also State of Victoria 2002).

Step 4: implementation of ***differential weightings*** to each habitat attribute

Each "component" (= site-condition and landscape-context attributes) are given by Parkes et al. (2003) a weight in such a way that the sum of these weights amounts to 100. These weights are called "maximum value" (Tab. 8) and are supposed to be expressed in %.

Comment: Firstly, I fail to see for instance a clear and convincing rationale why *presence of logs* gets weighting value 5 and why *lack of weeds* scores 15. At best this weighting is very subjective and such can be easily manipulated. Secondly, the scoring of *recruitment of woody perennial native species* uses three levels of decision ending up in two numerical scales – both of them are nominal although they present to be ordinal. (This fact will have fallout at the point of calculation of "Final Habitat Score"!)

Step 5: ***scoring of habitat attributes*** and ***construction of summary index*** – calculation of Final Habitat Score

The calculation of the "Final Habitat Score" is the culmination of the whole procedure. According to Parkes et al. (2003) "the final 'habitat score' for the stand is determined by recording and tallying the scores from all 'site condition' and 'landscape context' components and standardizing scores if required by the benchmark. Multiplying the ‘habitat score’ by the area of the stand offers a quality-quantity measure that is termed a ‘habitat hectare’. The ‘habitat score’ represents the proportion of the complete ‘habitat’ present and the highest score possible is 100 points.”

Comment: McCarthy et al. (2004) criticised three internal inconsistencies of the method which combines the attributes into a Final Habitat Score.

(1) The first inconsistency relates to the way scores are allocated for individual attributes. McCarthy et al. (2004) brought also an example which showed lack of logic of some of the allocations. I wish to add that I fail to see clear and convincing reasoning for values assignments as used for instance in *ground level litter* these scales are 0,3, 5 and 0,2,4 while in *area of nominated patch* the scale spans 1,2,3,4,6,8,10 (see Tabs. 7 and 8 in Parkes et al. 2003, resp.). Why values 5, 7 and 9 had been left out from the latter scale?

(2) McCarthy et al. (2004) are suggested that adding of scores assumes that different habitat attributes are substitutable (see also Burgman et al. 2001). Instead they suggest using a multiplicative approach (base don weighted geometric average of scores) such that complete compensation for a reduction in one attribute would require a much larger increase in another attribute. Parkes et al.’s (2004) response to this valid point fell not short of ridiculous as they defended they stand by words: “Any mathematical benefit must be weighted against the additional complexity to field staff, and more sophisticated approach may increase mistake in calculations in the field and reduce accessibility to landholders”. I am suggesting, however, that the situation is more serious. The assessment scales (values of the attributes) cannot be and should not be combined (either using summation or multiplication) in a manner as it was done by Parkes et al. (2003) simply because some of these scales are either ***nominal*** (such as *regeneration of woody perennial native species, area of the nominated patch, distance to core area*) or at best they pretend to be ***ordinal***. One way or another, the fact that neither nominal nor ordinal data are liable to arithmetic operations such as addition or multiplication (see Stevens 1946 and any of modern statistical textbook), renders the calculations suggested and performed by Parkes et al. (2003) as meaningless (Wolman 2006). The values of the Final Habitat Score are then as informative as the numbers of houses in a street.

(3) The third concern articulated by McCarthy et al. (2004) is the mathematical logic behind the multiplication of habitat score by the area of vegetation to obtain the measure of habitat hectares (with the units of the habitat scores being habitat per ha). Indeed, the logic of this deep escapes my understanding too, in particular when facing the lack of meaningfulness of the “calculated” final habitat values. Yet, Parkes et al. (2003) might have here stumbled over something potentially useful – an idea of combining the notion of habitat quality and habitat quantity into a viable, informative index with a strong socio-economic potential. Such index has been actually in development in times when the HH approach has been presented and discussed (roughly 2002-2005) by a group of Dutch researchers (De Heer 2002, Tekelenburg et al. 2004, ten Brink 2000, ten Brink & Tekelenburg 2002). The index is called ***Natural Capital Index (NCI)*** and it combines qualitative and quantitative information on the state of habitats and their biological diversity by computing a 2-dimensional product (habitat quality X habitat quantity). NCI developed to evaluate whether or not progress is being made towards one of the three central objectives of the Convention on Biological Diversity (UNEP 1999), the objective of conservation of biodiversity (Bredemeier in Cocciufa et al. 2008). Neither Parkes et al. (2003) nor McCarthy et al. (2004) were apparently aware of this development (judging form the list of references in their respective papers) The obvious similarities between

the HH approach and NCI were, however, recognized by Hungarian researchers (Czúcz et al. 2008 and submitted). Naturally, the calculation of NCI requires values of both multiplied variables in ratio scale – requirements which HH does not provide for.

The New South Wales *BioMetric* vegetation condition assessment tool share a number of important features with the HH approach. Perhaps importantly, it involves also very contentious calculation of the summary index (see for instance Gibbons et al. 2005, Gorrod & Keith 2009) which disqualifies this tool as serious contender for application either in Western Australia or as the general tool of the Commonwealth.

The *BioCondition* tool used in Queensland is in all vital aspects similar to HH approach with regard to (1) nature of the assessment unit (plot), (2) suite of vegetation condition attributes that act as surrogates or indicators of biodiversity values, (3) application of Benchmarks for each of the attributes for each regional ecosystem, (4) similar assessment methodology, and (5) scoring system allowing for calculation (albeit in a dodgy way from the mathematical a point of view) of a final "condition" score (Eyre et al. 2004, 2006, 2008).

Zerger et al. (2006), obviously not very pleased with the HH approach, have developed their own version of a vegetation condition score calculation – this time derived from seven variables measured on each plot and representing vegetation structure (canopy cover, woody cover, non-woody ground vegetation cover, number of hollow-bearing trees, mature trees) and some aspects of function including tree dieback and tree regeneration. Zerger et al.'s (2006) method is in principle similar to that of HH by Parkes et al. (2003) in (i) assigning a score the value recorded for each variable on each plot (in their particular case the scores were ranked 0 to 3), (ii) summing these scores across all variables for each plot, and (iii) scaling the summed values within a range (in this particular case from 0 to 10). The score from 0 to 3 for each variable was calculated by comparing the measured value for each variable with benchmarks derived from an independent dataset (for more details see Zerger et al. 2006, p. S38). The nature of scoring of values shows that the used scale is ordinal. The summation of the values and subsequent scaling (involving the arithmetic operation of division) are then invalid, hence render the final assessment score equally meaningless as in the HH method.

Because of the point-based (or patch-based) nature of the assessments such as HH or BioMetric, translation of the point data to two-dimensions (= construction of a map of landscape or region and beyond) is a major challenge. As noted rightly by Newell et al. (2006), highly variable nature of condition across landscapes means that this information does not necessarily infer the condition of other adjacent sites, hence use simple distance-weighted extrapolation algorithms is hardly a reasonable option. In order to overcome this problem, Newell et al. (2006) used a large data set of plots for which a final HH value was calculated and then used as the dependent variable in a 'neural network' modelling procedure (e.g. Lek & Guégan 1999). This method attempts to identify relationships between site condition scores and 13 selected independent variables such as vegetation type, climate and lithology, indices of tree density and a land-use map. The output of this modeling identified relationships between the 13 independent variables and site condition assessed in the field, with a strong positive correlation evident between the predicted and observed scores explaining 51% of the variance. The modelled ‘neural network’ relationships were then applied to ‘unknown’ sites or cells (30 m^2 large) with recognized extant native terrestrial vegetation to form a condition map that was coincident with extant native vegetation. Further independent set comprising data on more than 500 sites was then collected to validate the map (see Fig. 11). Higgins (2006) reported that the vegetation conditions maps generated by Newell et al. (2006) had been used to calculate conservation significance and conservation status maps.

Zerger et al. (2006) set off to tackle the same problem and built a model of vegetation condition using generalized additive modelling (GAM) with the Generalized Regression Analysis for Species Prediction (GRASP) framework (Lehman et al. 2003a, b). They used the condition scores generated by their own vegetation condition assessment method (see above) as response variable, and a set of explanatory variables, among them a series of remote-sensed data derived form SPOT4 imagery (see Tab. 1 in Zerger et al. 2006). A map generated by Zerger et al. (l.c.) the GAM modelling combined with GIS is reproduced in Fig. 12.

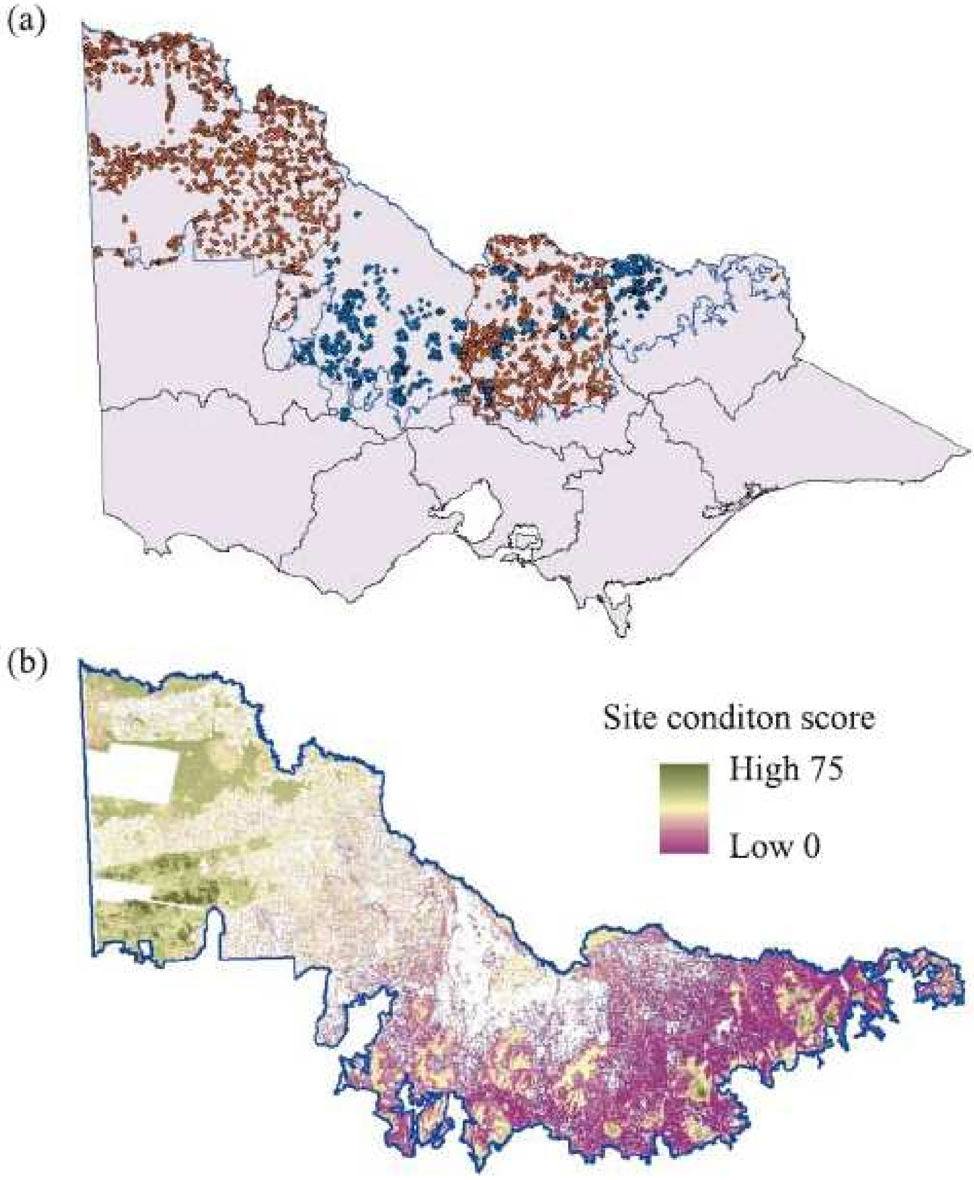


Fig. 11. Example of Habitat Hectares mapping of northern Victoria. (a) sample points, blue: old, maroon: new; (b) modelled vegetation condition based on the data featured in Fig. 9a. (after Newell et al. 2006).

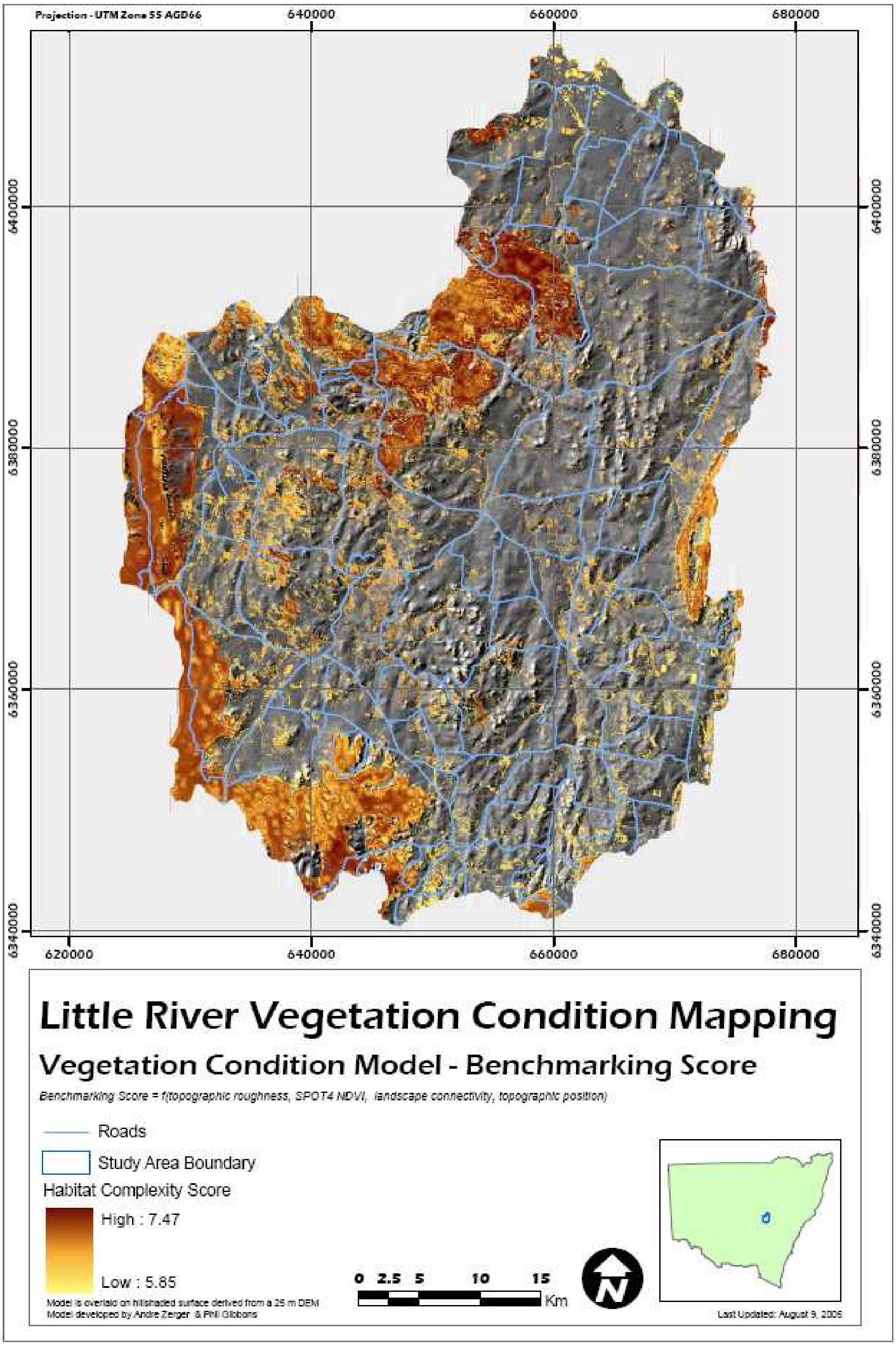


Fig. 12. Vegetation condition model for the Little River Catchment (from Zerger et al. 2006).

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