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Evaluating multifunctionality and adaptive capacity of mountain forest management alternatives under climate change in the Eastern Alps

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Electronic Supplementary Material

1. SM1:Ecosystem service indicators

In Table SM1-1 all ecosystem service indicators used in this study are presented with details on measurement units, aggregation and preference direction.

Tab SM1-1 Ecosystem service indicators and the regeneration indicator (REG) as used in this study.

Acronym	Short description	unit	temporal aggregation	spatial grainsize	Preference direction
Timber production					
THV	Timber harvested	m ³ ha ⁻¹ yr ⁻¹	mean	harvesting unit	more
VI	Volume increment	m ³ ha ⁻¹ yr ⁻¹	mean	harvesting unit	more
BBD	Bark beetle damage	m ³ ha ⁻¹ yr ⁻¹	mean	harvesting unit	less
V	Standing Timber	m ³ ha ⁻¹	mean	harvesting unit	optimum
Carbon sequestration					
C	Carbon	t ha ⁻¹	mean	harvesting unit	more
Nature conservation					
DSP	Species Diversity	[Index]	mean	1ha cell	more
DSI	Size Diversity	[Index]	mean	1ha cell	more
BHQ	Bird Habitat Quality	[good, medium, poor]	mode	1ha cell	More (area [good])
Protection against gravitational hazards					
API	Protection against snow avalanches	[0-1]	minimum	1ha cell	More
LPI	Protection against landslides	[good, medium, poor]	lowest	1ha cell	More (area [good])
RPI	Protection against rockfall	[0-0.99]	minimum	1ha cell	More
Forest regeneration					
REG	area with regeneration	[%]	mean	1ha cell	more

Below follows a detailed description of the employed ecosystem service indicators (compare Table SM1-1).

Timber production:

V: Volume of life trees with minimum diameter at breast height (DBH) of 5cm.

TVH: Total annual volume of trees harvested with minimum DBH of 5cm.

VI: periodic annual volume production of trees with minimum DBH of 5cm.

BBD: Annual timber volume killed by bark beetle infestations with minimum DBH of 5cm.

Carbon sequestration:

C: Total carbon contained in tree biomass for trees with minimum DBH of 5cm (above and belowground), includes carbon contained in live trees, standing deadwood carbon, carbon contained in woody debris and carbon contained in soil organic matter.

Nature conservation:

DSP: Tree species diversity calculated as relative true diversity index according to Jost (2006), using basal area of trees with DBH >5cm. This index can be interpreted as an “equivalent number of species” as it equals tree species richness when all species in the stand are equally abundant. Otherwise, it is always below tree species richness (see Eq. 1)

$$DSP = \exp(H) \quad (1)$$

$$H = -\sum_{i=1}^S p_i \ln(p_i)$$

Where S is the number of tree species and p_i is the relative basal area share of species (i).

DSI: Tree size diversity calculated as the mean of the Shannon entropy indices applied to basal area in diameter classes and height classes respectively, as presented in Cordonnier et al (2013) (see Eq. 2). For diameter classes (5cm classes) minimum DBH is 5cm, for height classes (2m classes) minimum tree size is 4m.

$$DSI = \frac{H_{DBH} + H_H}{2} \quad (2)$$

$$H_{DBH} = -\sum_{m=1}^{N_{DBH}} p_m \ln(p_m)$$

$$H_H = -\sum_{n=1}^{N_H} p_n \ln(p_n)$$

Where N_{DBH} is the number of 5cm DBH classes, N_H is the number of 2m height classes, p_m is the relative basal area within a DBH class and p_n is the relative basal area within a height class.

BHQ: The bird habitat indicator assesses quality of forest habitat elements for bird species. The used indicator is a modification of the version presented in Cordonnier et al (2013). BHQ is measured on ordinal scale (categories: good, medium, poor) and is composed of standing deadwood (trees with DBH<30cm), large living trees (DBH>50cm) and canopy cover (DBH>5cm) of a forest (see Table SM2). If two of the three sub-indicators are classified as “good”, the BHQ is “good”, for “medium” two indicators have to be at least classified as “medium”. Rating is “poor” if the criteria for “good” or “medium” are not met.

Tab SM1-2 Sub-indicators for the Bird habitat Quality index (BHQ).

Sub-indicator	acronym	Requirements for BHQ categories		
		good	medium	poor
Volume of standing dead trees [m ³ ha ⁻¹]	DVW	DVW > 35	15 < DVW < 35	DVW < 15
Number living trees [n ha ⁻¹]	LLTN	LLTN > 20	10 < LLTN < 20	LLTN < 10
Canopy cover [%]	CC	60 < CC < 80	(80 < CC < 90) ∪ (40 < CC < 60)	(CC > 90) ∪ (CC < 40)

Protection against gravitational hazards:

API: The avalanche protection index indicates protection against snow avalanche release. It has been presented in Cordonnier et al. (2013) based on Frehner et al. (2005) and Gauquelin & Courbaud (2006). The index is calculated from mean slope, basal area and average diameter (for trees with DBH >5cm) (Eq. 3). API varies between 0 and 1, where 1 indicates efficient protection.

$$API = \min \left[\frac{G}{(0.2901 * \overline{DBH} + 1.494) \times (0.1333 * s - 3)}; 1 \right] \quad (3)$$

Where G is basal area of trees >5cm [m² ha⁻¹], $\overline{DBH}$ is mean DBH of trees >5cm [cm] and s is slope [°].

LPI: The indicator for landslide and erosion protection has been presented in Cordonnier et al. (2013) based on Berger (1997) and Frehner et al. (2005). It builds on crown cover defined by canopy crown area cover for trees with DBH >5cm. LPI is ordinally scaled in three categories:

Poor: canopy cover < 30%

Medium: 30% ≤ canopy cover < 60%

Good: canopy cover ≥ 60%

RPI: The indicator for rockfall protection estimates protection against rockfall in transit and deposit zones. Formulae are based on the tool simulation Rockfor-net presented in Berger and Dorren (2007). See also <http://www.ecorisq.org/rockfor-net-en>. RPI varies between 0 and 0.99, where 0.99 means that 99% of passing rocks are stopped by a forest. For this study we calculated indices for different rock sizes. RPI was calculated for rock diameter 0.46m and density 2400kg/m³. Initial fall height was set to 20m. Eq. (4a) is used for cells with basal area >10m²ha⁻¹, Eq. (4b) for cells with basal area <10m² ha⁻¹.

$$A = \frac{(\Phi_{rock} \times N \times 100 \times \cos(s)) \times (EvG + (DcD \times 1.7)) * 38.7 * \overline{DBH}^{2.31}}{3.352 \times 10^4 \times \left[0.5 \times \rho \times \pi \times \left(\frac{\Phi_{rock}}{2} \right)^3 \times \left[\min \left(\sqrt{2 \times 9.81 \times \left(F_{ih} + \left(\frac{100}{\cos(s)} \right) \times \max(\tan(s) - 0.6; 0.00086)} \right)}; 0.64 \times s \right)^2 \right] + 0.25 \times \rho \times \pi \left(\frac{\Phi_{rock}}{2} \right)^3 \times F_{ih}} \quad (4a)$$

$$RPH = \max(0.01; 1 - A)$$

$$RPI = 1 - \max(0.01; 1 - A)$$

$$B = \frac{(\Phi_{rock} \times N \times 100 \times \cos(s)) \times (EvG + (DcD \times 1.7)) * 38.7 * \overline{DBH}^{2.31}}{3.352 \times 10^4 \times \left[0.5 \times \rho \times \pi \times \left(\frac{\Phi_{rock}}{2} \right)^3 \times \left[\min \left(\sqrt{2 \times 9.81 \times \left(F_{ih} + \left(\frac{100}{\cos(s)} \right) \times \max(\tan(s) - 0.6; 0.00086)} \right)}; 0.8 \times s \right)^2 \right] + 0.25 \times \rho \times \pi \left(\frac{\Phi_{rock}}{2} \right)^3 \times F_{ih}} \quad (4b)$$

$$RPH = \max(0.01; 1 - B)$$

$$RPI = 1 - \max(0.01; 1 - B)$$

Where N is the number of trees >5cm, s is slope [°], EvG is basal area share of evergreen species [%], DcD is basal area share of deciduous species [%], $\overline{DBH}$ is mean DBH of trees >5cm [cm], Φ_{rock} is rock diameter [m], ρ is rock density [kg m⁻³] and F_{ih} is initial free fall height of rocks [m]

REG: Regeneration indicator. It is calculated as the share of 1ha grid cells with at least 50 saplings per ha in height class 80-130cm.

Literature

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2. SM2: Model parameters for browsing algorithm

Tab SM2-1 Model parameters for the PICUS browsing submodule. browsing probability = annual fraction of simulated patches experiencing browsing; mortality fraction = fraction of stems per simulated patch in height class (i) exceeding the allowed number of successive years with height growth below the threshold that die; required height growth = minimum height growth per year; years below threshold = number of successive years below the required height growth threshold;

Model parameter	spruce	fir	maple	beech
browsing:				
browsing probability	0.31	0.68	0.41	0.38
mortality:				
mortality fraction	0.63	0.57	0.57	0.63
required height growth [cm/yr]				
height class 0-10cm	3	3	3	3
height class 10-30cm	3	3	5	3
height class 30-80cm	2	1	5	3
height class 80-130cm	2	1	5	3
years below threshold [yr]	5	5	2	3

3. SM3: Model-induced variability of ES indicators

In general, model-induced variability in indicators increased over time. Focusing on final assessment period P3, we observed some distinct patterns (see Fig. SM3-1): First, stochastic variation of indicators that scale linearly and are aggregated at the level of harvesting units (V, C, VI, and TVH) was very low (management-specific CVs <1.5% under current climate c0) and increased only slightly under the most severe temperature increase of scenarios c4 and c5 (CV = 2-2.5%), with VI as the only exception (highest CVs under c2). The diversity indicators DSP and DSI showed a very similar behaviour. Variation of DSI was particularly low (CVs <0.2%). For these indicators the effect of climate on indicator variability was significant for TVH, VI and V only (Table SM3-2). Second, management-specific coefficients of variation for the indicators BHQ, LPI, API, RPI and REG were in general moderately larger (CV = 2-8%). From all indicators the bark beetle induced damage in timber volume (BBD) clearly showed the highest variability (CV = 9-17% per management alternative). Within this indicator group the effect of climate on indicator variability was significant for the protection indicators LPI and RPI. Interestingly, variation in BBD decreased with increasing climate change severity with variability clearly being smallest under the warmest climate scenario c5. Detailed analysis revealed that with increasing severity of climate change damages by bark beetles occurred more regularly, and as a consequence variation between simulation runs decreased.

Overall, the absolute differences in CV between management alternatives were very small within a specific climate scenario (0.5-4%) with the exception of BBD, where they were as large as 8%. For DSP, DSI, BHQ and RPI, management affected indicator variation significantly (Table SM3-2). Most indicators exhibited highest variability under the NOM and SAN management alternatives, with the exception of RPI, LPI, C, V and BBD, that showed the largest variation under the PATCH-LO management. There was no interacting effect of climate and management on the variability of indicators.

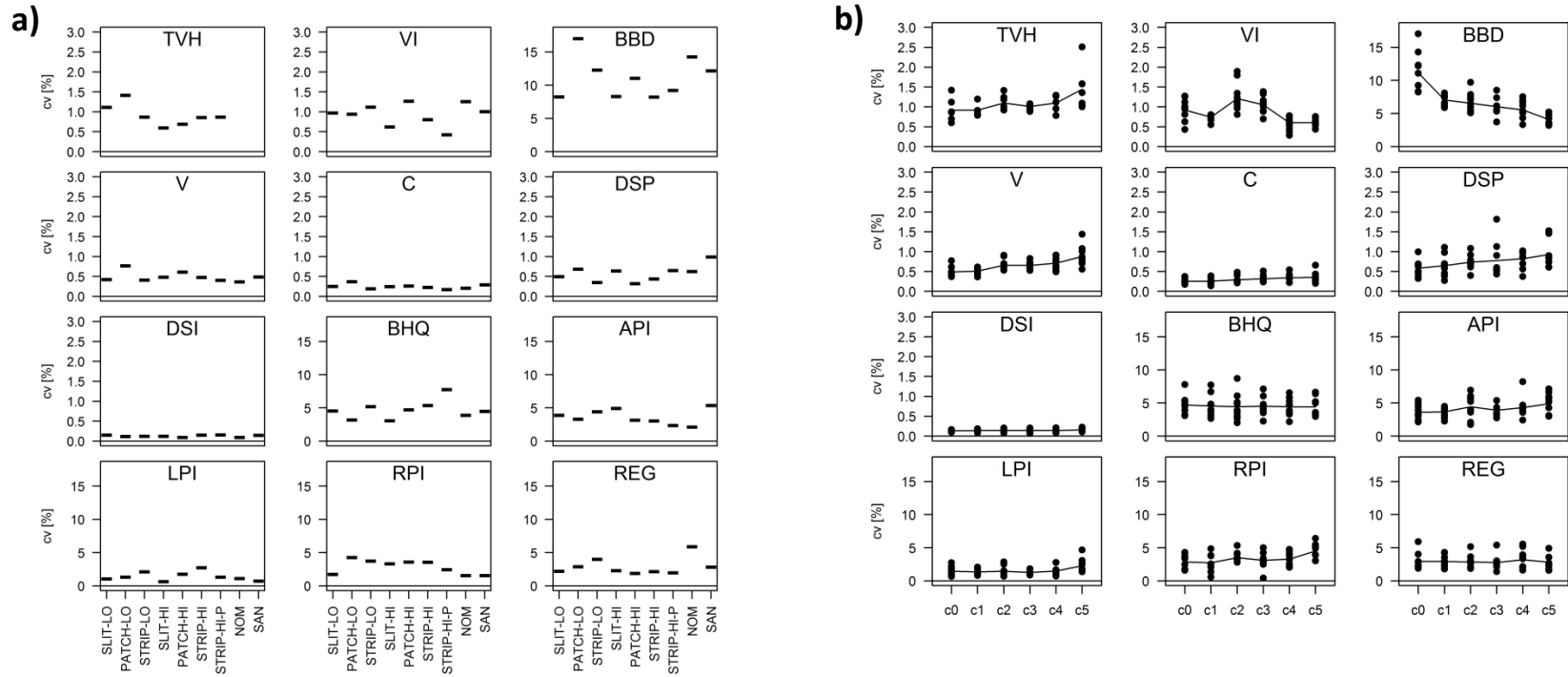


Fig SM3-1 Panel a) Variability of indicators under historic climate (c0). Coefficient of variation (CV) in period P3 (2067-2100) based on 10 repetitions. Panel b) Variability of indicators under climate change (n per climate scenario: 9 management alternatives x 10 simulation repetitions); TVH = timber harvests, VI = annual volume increment, BBD = damage by bark beetle disturbances, V= timber volume stock, C= carbon stock, DSP= tree species diversity, DSI = tree size diversity, BHQ = bird habitat quality, API = avalanche protection, LPI = landslide protection, RPI= rockfall protection, REG = regenerated area. DSP and DSI are represented by 50th-percentile, API and RPI by 10th-percentile and LPI and BHQ as share of area rated as “good”. Black line shows fitted cubic smoothing spline (DF=5).

Table SM3-2 F-values for ANOVA test for difference of variation (calculated as CV) for model repetitions between management scenarios (DF=8), climate scenarios (DF=5) and interaction management x climate (DF=40). ***= Pr < 0.001, **=Pr<0.01, *= Pr<0.05, n.s. = Pr>0.05; # = salvaged timber left on site is not included.

	TVH [#]	VI	VBB	V	C	DSP	DSI	BHQ	API	LPI	RPI	REG
management	0.53 n.s.	2.33 n.s.	0.02 n.s.	1.07 n.s.	3.67 n.s.	13.29 ***	9.41**	5.01*	0.14 n.s.	2.36 n.s.	9.30**	3.44 n.s.
climate	4.37**	14.35***	17.80***	7.73***	1.92 n.s.	2.10 n.s.	0.65 n.s.	0.05 n.s.	1.53 n.s.	2.61*	3.91**	0.24 n.s.
management:climate	2.14 n.s.	1.49 n.s.	0.56 n.s.	0.90 n.s.	0.89 n.s.	1.46n.s.	0.36 n.s.	0.48 n.s.	1.68n.s.	0.06 n.s.	1.00 n.s.	0.10 n.s.

4. SM4: Longterm effects of management and climate on ES provisioning

Table SM4-1 F-values for ANOVA test for effects of management (DF=8), climate scenarios (DF=5) and interaction of management x climate (DF=40). P10, P50, P90 = 10th, 50th, and 90th percentile. ***= Pr <0.001, **=Pr<0.01, *= Pr<0.05, n.s.=Pr>0.05; # = salvaged timber not included; empty fields = test not applicable because at least one group showed no variation.

Factor	Period	TVH [#]	VI	BBD	V
management	1	462233.0***	4411.1***	4.9***	10308.2***
climate	1	135.3***	17305.6***	846.7***	657.1***
management:climate	1	8.4***	5.4***	1.3***	4.3***
management	2	198491.7***	1977.2***	19.6***	39844.4***
climate	2	355.5***	3186.8***	4976.3***	2069.2***
management:climate	2	22.5***	5.0***	5.1***	2.9***
management	3	146603.5***	4818.2***	182.1***	41906.4***
climate	3	3512.8***	10921.5***	5028.9***	12010.0***
management:climate	3	144.6***	24.3***	23.2***	32.5***

Factor	Period	DSP P10	DSP P50	DSP P90	DSI P10	DSI P50	DSI P90	BHQ (poor)	BHQ (med)	BHQ (good)
management	1		376.3***	161.9***	522.4***	522.4***	169.7***	69.4***	58.4***	152.1***
climate	1		313.9***	133.1***	38.7***	38.7***	130.2***	2.0	4.8***	8.9***
management:climate	1		3.0***	1.7**	4.2***	4.2***	7.0***	1.4*	2.8***	4.0***
management	2		5427.4***	2933.9***	4742.3***	4742.3***	10203.0***	186.4***	301.6***	666.4***
climate	2		1814.5***	1062.3***	262.0***	262.0***	365.6***	29.8***	66.1***	144.2***
management:climate	2		17.0***	8.1***	8.5***	8.5***	5.4***	3.7***	4.7***	7.1***
management	3		23765.0***	8405.3***	3852.7***	3852.7***	7078.3***	336.2***	302.5***	1002.1***
climate	3		1973.7***	2523.9***	559.0***	559.0***	718.4***	28.5***	61.1***	40.2***
management:climate	3		120.1***	28.8***	10.4***	10.4***	21.9***	4.0***	7.9***	17.8***

Factor	Period	API P10	API P50	API P90	LPI (poor)	LPI (med)	LPI (good)	RPI P10	RPI P50	RPI P90
management	1	852.7***			1264.0***	2307.1***	5905.0***	336.4***		
climate	1	24.3***			18.2***	6.5***	27.2***	59.6***		
management:climate	1	2.8***			1.6*	1.6***	2.1***	3.6***		
management	2	793.7***			1283.6***	7077.1***	10273.9***	3205.6***		
climate	2	62.4***			36.5***	425.9***	580.1***	158.0***		
management:climate	2	2.6***			3.3***	12.1***	14.5***	2.6***		
management	3	84.0***			264.9***	2874.5***	4074.5***	4661.4***		
climate	3	124.3***			55.0***	910.4***	1275.8***	977.7***		
management:climate	3	3.2***			3.5***	15.0***	19.3***	18.4***		

Tab SM4-2 Ecosystem service indicators for management alternatives under historic climate (c0) in assessment period P3 (2067-2100), P10, P50, P90 = 10th, 50th, and 90th percentile, mean of 10 simulation runs, Tukey tests for significant differences between management scenarios under historic climate conditions (c0), letters denote significant (alpha = 0.05) differences between management scenarios, NA = excluded from test

Indicator	Unit		SLIT-LO	PATCH-LO	STRIP-LO	SLIT-HI	PATCH-HI	STRIP-HI	STRIP-HI-P	NOM	SAN
THV	m ³ ha ⁻¹ yr ⁻¹	mean	2.6 d	2.6 d	2.3 e	2.8 c	3.3 b	3.9 a	3.9 a	0.0 NA	0.0 NA
VI	m ³ ha ⁻¹ yr ⁻¹	mean	6.5 d	6.6 d	6.9 c	7.0 bc	7.0 b	7.3 a	7.3 a	5.9 e	5.9 e
BBD	m ³ ha ⁻¹ yr ⁻¹	mean	0.5 ab	0.5 ab	0.5 ab	0.5 a	0.5 a	0.5 a	0.4 b	0.5 ab	0.4 b
V	m ³ ha ⁻¹	mean	438.2 c	438.1 c	444.9 b	375.0 d	352.1 f	352.4 f	365.6 e	553.0 a	554.3 a
C	t ha ⁻¹	mean	226.9 d	227.1 d	228.1 c	209.8 e	202.8 g	202.5 g	207.6 f	264.0 a	260.0 b
<i>DSP</i>	-	P10	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.09 n.s.	1.00 n.s.	1.00 n.s.
		P50	1.06 d	1.06 d	1.04 f	1.09 b	1.07 c	1.05 e	1.54 a	1.05 de	1.10 b
		P90	1.67 c	1.67 c	1.59 d	1.72 b	1.68 c	1.54 e	2.39 a	1.67 c	1.70 bc
<i>DSI</i>	-	P10	2.66 d	2.66 d	2.67 c	2.70 a	2.71 a	2.69 b	2.71 a	2.57 e	2.57 e
		P50	2.71 e	2.71 de	2.71 d	2.75 a	2.75 a	2.74 c	2.74 b	2.63 f	2.63 f
		P90	2.74 d	2.74 d	2.75 c	2.77 b	2.77 ab	2.77 ab	2.78 a	2.66 e	2.67 e
<i>BHQ</i>	%	poor	10.0 de	9.2 e	10.9 cd	11.8 bc	12.8 b	15.3 a	15.6 a	9.1 e	11.5 bc
		medium	40.5 NA	40.6 NA	46.5 NA	43.6 NA	42.8 NA	49.0 NA	51.9 NA	45.7 NA	53.6 NA
		good	49.6 a	50.2 a	42.6 b	44.6 b	44.4 b	35.7 c	32.6 d	45.1 b	35.0 cd
<i>API</i>	-	P10	0.86 bc	0.86 bc	0.82 c	0.85 bc	0.76 d	0.75 d	0.82 c	0.91 a	0.87 ab
		P50	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.
		P90	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.	1.00 n.s.
<i>LPI</i>	%	poor	5.9 c	5.5 c	5.5 c	5.7 c	6.5 b	7.1 a	5.5 c	4.4 d	4.1 d
		medium	24.4 NA	24.4 NA	29.8 NA	29.0 NA	31.0 NA	42.5 NA	35.2 NA	18.6 NA	17.2 NA
		good	69.7 c	70.1 c	64.7 d	65.3 d	62.5 e	50.4 g	59.4 f	77.0 b	78.7 a
<i>RPI</i>	-	P10	0.65 b	0.66 b	0.56 c	0.54 c	0.50 d	0.43 e	0.50 d	0.98 a	0.98 a
		P50	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.
		P90	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.	0.99 n.s.

Tab SM4-3 Ecosystem service indicators for chosen management types under climate change (c1) in assessment period P3 (2067-2100), P10, P50, P90 = 10th, 50th, and 90th percentile, mean of 10 simulation runs, Tukey tests for significant differences between management scenarios under climate change conditions (c1), letters denote significant (alpha = 0.05) differences between management scenarios, NA = excluded from test

Indicator	Unit		SLIT-LO	PATCH-LO	STRIP-LO	SLIT-HI	PATCH-HI	STRIP-HI	STRIP-HI-P	NOM	SAN
THV	m ³ ha ⁻¹ yr ⁻¹	mean	2.7 e	2.6 f	2.3 g	2.8 d	3.3 c	3.9 b	3.9 a	0.0 h	0.0 h
VI	m ³ ha ⁻¹ yr ⁻¹	mean	7.4 d	7.4 d	7.9 c	7.9 bc	8.0 b	8.4 a	8.3 a	6.7 e	6.7 e
BBD	m ³ ha ⁻¹ yr ⁻¹	mean	1.1 cde	1.2 bcd	1.2 abc	1.1 de	1.1 cde	1.1 de	1.0 e	1.3 ab	1.3 a
V	m ³ ha ⁻¹	mean	444.5 c	442.8 c	450.3 b	380.4 d	358.5 f	360.6 f	376.5 e	558.3 a	558.5 a
C	t ha ⁻¹	mean	228.0 c	227.9 c	228.7 c	211.2 d	204.6 e	204.0 e	210.4 d	264.4 a	260.7 b
<i>DSP</i>	-	P10	1.00 de	1.00 d	1.00 e	1.02 b	1.02 b	1.00 de	1.14 a	1.00 de	1.01 c
		P50	1.11 d	1.11 d	1.07 f	1.17 c	1.16 c	1.09 e	1.69 a	1.08 e	1.18 b
		P90	1.84 c	1.84 cd	1.69 e	1.94 b	1.92 b	1.67 e	2.72 a	1.80 d	1.91 b
<i>DSI</i>	-	P10	2.64 c	2.64 c	2.64 c	2.68 a	2.69 a	2.67 b	2.69 a	2.55 e	2.57 d
		P50	2.69 c	2.69 c	2.69 c	2.73 a	2.73 a	2.71 b	2.73 a	2.61 e	2.63 d
		P90	2.72 e	2.72 de	2.73 d	2.76 b	2.76 ab	2.75 c	2.76 a	2.65 g	2.66 f
<i>BHQ</i>	%	poor	9.09 d	8.82 d	8.95 d	11.00 c	11.45 c	14.59 b	16.82 a	8.55 d	13.32 b
		medium	40.18 f	39.00 f	45.59 cd	43.41 de	45.77 cd	46.64 c	50.77 b	41.91 ef	53.86 a
		good	50.73 a	52.18 a	45.45 b	45.59 b	42.77 b	38.77 c	32.41 d	49.55 a	32.82 d
<i>API</i>	-	P10	0.84 b	0.83 bc	0.80 cd	0.83 bcd	0.74 f	0.75 ef	0.79 de	0.88 a	0.83 bc
		P50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
<i>LPI</i>	%	poor	5.64 cd	5.36 cd	5.41 cd	5.73 bc	6.23 ab	6.50 a	5.09 d	4.32 e	4.18 e
		medium	22.77 NA	23.14 NA	29.50 NA	26.68 NA	29.68 NA	41.77 NA	32.82 NA	18.27 NA	16.91 NA
		good	71.59 c	71.50 c	65.09 e	67.59 d	64.09 e	51.73 g	62.09 f	77.41 b	78.91 a
<i>RPI</i>	-	P10	0.68 b	0.69 b	0.57 c	0.55 cd	0.51 e	0.45 f	0.54 d	0.98 a	0.99 a
		P50	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
		P90	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Tab SM4-4 Ecosystem service indicators for management types under climate change (c2) in assessment period P3 (2067-2100), P10, P50, P90 = 10th, 50th, and 90th percentile, mean of 10 simulation runs, Tukey tests for significant differences between management scenarios under climate change conditions (c2), letters denote significant (alpha = 0.05) differences between management scenarios, NA = excluded from test

Indicator	Unit		SLIT-LO	PATCH-LO	STRIP-LO	SLIT-HI	PATCH-HI	STRIP-HI	STRIP-HI-P	NOM	SAN
THV	m ³ ha ⁻¹ yr ⁻¹	mean	2.5 e	2.4 e	2.1 f	2.5 d	3.0 c	3.5 b	3.6 a	0.0 NA	0.0 NA
VI	m ³ ha ⁻¹ yr ⁻¹	mean	6.5 c	6.6 c	6.9 b	6.9 b	7.0 b	7.3 a	7.3 a	5.9 d	5.9 d
BBD	m ³ ha ⁻¹ yr ⁻¹	mean	1.6 ab	1.5 bc	1.6 ab	1.4 cd	1.4 cd	1.4 cd	1.3 d	1.7 a	1.7 a
V	m ³ ha ⁻¹	mean	403.8 bc	400.8 c	406.6 b	344.5 d	321.8 e	324.0 e	342.1 d	512.7 a	508.8 a
C	t ha ⁻¹	mean	218.9 c	218.4 c	219.0 c	203.1 d	196.2 e	196.0 e	203.0 d	254.0 a	251.8 b
<i>DSP</i>	-	P10	1 d	1 d	1 d	1.01 c	1.01 c	1 d	1.15 a	1 d	1.02 b
		P50	1.11 de	1.11 d	1.07 g	1.16 c	1.16 c	1.09 fg	1.73 a	1.1 ef	1.25 b
		P90	1.9 d	1.91 d	1.76 f	1.96 c	1.95 c	1.73 f	2.83 a	1.86 e	2.05 b
<i>DSI</i>	-	P10	2.66 bc	2.67 b	2.66 c	2.7 a	2.7 a	2.7 a	2.71 a	2.58 e	2.6 d
		P50	2.71 d	2.72 c	2.71 d	2.74 a	2.74 a	2.72 b	2.74 a	2.64 f	2.66 e
		P90	2.74 c	2.74 c	2.74 c	2.77 ab	2.77 a	2.76 b	2.77 a	2.67 e	2.69 d
<i>BHQ</i>	%	poor	10.0 cd	8.5 d	10.6 c	13.5 b	14.2 b	16.2 a	17.6 a	8.7 d	13.0 b
		medium	39.6 NA	38.6 NA	42.8 NA	42.1 NA	44.4 NA	49.1 NA	50.8 NA	39.0 NA	53.1 NA
		good	50.5 a	52.9 a	46.6 b	44.5 b	41.4 c	34.7 d	31.6 e	52.4 a	34.0 de
API	-	P10	0.81 b	0.81 b	0.79 bc	0.79 b	0.73 c	0.77 bc	0.76 bc	0.87 a	0.80 b
		P50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LPI	%	poor	6.1	5.4	5.6	5.9	6.5	6.9	5.0	4.3	4.2
		medium	25.8 NA	26.3 NA	31.2 NA	30.1 NA	32.1 NA	44.3 NA	35.3 NA	19.9 NA	18.4 NA
		good	68.1 c	68.4 c	63.3 d	64.1 d	61.4 e	48.9 g	59.8 f	75.8 b	77.4 a
RPI	-	P10	0.58 c	0.6 c	0.52 d	0.5 d	0.45 e	0.41 f	0.5 d	0.87 b	0.92 a
		P50	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
		P90	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Tab SM4-5 Ecosystem service indicators for management types under climate change (c3) in assessment period P3 (2067-2100), P10, P50, P90 = 10th, 50th, and 90th percentile, mean results of 10 simulation runs, Tukey tests for significant differences between management scenarios under climate change conditions (c3), letters denote significant (alpha = 0.05) differences between management scenarios, NA = excluded from test

Indicator	Unit		SLIT-LO	PATCH-LO	STRIP-LO	SLIT-HI	PATCH-HI	STRIP-HI	STRIP-HI-P	NOM	SAN
THV	m ³ ha ⁻¹ yr ⁻¹	mean	2.6 d	2.6 d	2.3 e	2.7 c	3.3 b	3.8 a	3.8 a	0.0 NA	0.0 NA
VI	m ³ ha ⁻¹ yr ⁻¹	mean	7.5 d	7.5 d	8.1 b	7.9 c	8.1 b	8.6 a	8.5 a	6.8 e	6.8 e
BBD	m ³ ha ⁻¹ yr ⁻¹	mean	1.5 a	1.6 a	1.6 a	1.4 b	1.4 bc	1.3 bc	1.2 c	1.6 a	1.6 a
V	m ³ ha ⁻¹	mean	432.8 c	431.8 c	443.0 b	373.1 d	350.3 f	357.5 e	372.5 d	549.3 a	550.4 a
C	t ha ⁻¹	mean	225.2 d	225.3 d	226.5 c	209.5 e	202.9 f	203.1 f	209.5 e	261.9 a	259.2 b
DSP	-	P10	1.01 c	1.01 cd	1 e	1.03 b	1.03 b	1.01 cd	1.18 a	1.01 de	1.03 b
		P50	1.14 d	1.15 d	1.09 f	1.21 c	1.21 c	1.1 e	1.78 a	1.11 e	1.25 b
		P90	1.92 c	1.92 c	1.75 e	2.03 b	2.03 b	1.75 e	2.86 a	1.85 d	2.03 b
DSI	-	P10	2.63 cd	2.64 c	2.63 d	2.69 a	2.68 a	2.67 b	2.69 a	2.55 f	2.57 e
		P50	2.69 c	2.69 c	2.68 d	2.73 a	2.73 a	2.7 b	2.73 a	2.61 f	2.63 e
		P90	2.72 c	2.72 c	2.72 c	2.75 a	2.76 a	2.74 b	2.76 a	2.64 e	2.66 d
BHQ	%	poor	9.3 e	8.4 e	9.6 e	12.0 d	12.6 cd	15.1 ab	16.6 a	8.2 e	13.9 bc
		medium	40.4 NA	38.1 NA	44.3 NA	42.4 NA	45.3 NA	46.8 NA	50.4 NA	41.7 NA	54.0 NA
		good	50.3 b	53.6 a	46.1 c	45.6 c	42.1 d	38.1 e	33.1 f	50. b	32.1 f
API	-	P10	0.81 c	0.81 c	0.86 ab	0.78 cd	0.72 e	0.76 de	0.79 cd	0.90 a	0.82 bc
		P50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LPI	%	poor	5.6	5.2	5.2	5.5	4.9	6.3	4.9	4.2	4.1
		medium	22.9 NA	23.5 NA	28.5 NA	26.7 NA	29.5 NA	40.6 NA	30.7 NA	19.1 NA	17.5 NA
		good	71.5 c	71.3 c	66.3 e	67.9 d	64.7 f	53.1 g	64.4 f	76.8 b	78.4 a
RPI	-	P10	0.66 c	0.68 c	0.59 d	0.56 de	0.52 f	0.47 g	0.55 ef	0.95 b	0.99 a
		P50	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
		P90	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Tab SM4-6 Ecosystem service indicators for management types under climate change (c4) in assessment period P3 (2067-2100), P10, P50, P90 = 10th, 50th, and 90th percentile, mean results of 10 simulation runs, Tukey tests for significant differences between management scenarios under climate change conditions (c4), letters denote significant (alpha = 0.05) differences between management scenarios, NA = excluded from test

Indicator	Unit		SLIT-LO	PATCH-LO	STRIP-LO	SLIT-HI	PATCH-HI	STRIP-HI	STRIP-HI-P	NOM	SAN
THV	m ³ ha ⁻¹ yr ⁻¹	mean	2.5 e	2.5 e	2.2 f	2.6 d	3.1 c	3.6 b	3.7 a	0.0 NA	0.0 NA
VI	m ³ ha ⁻¹ yr ⁻¹	mean	7.4 e	7.5 d	7.9 bc	7.9 c	8.0 b	8.4 a	8.4 a	6.7 f	6.7 f
BBD	m ³ ha ⁻¹ yr ⁻¹	mean	1.8 bc	2.0 ab	1.9 b	1.7 cd	1.7 d	1.7 d	1.4 e	2.1 a	2.0 ab
V	m ³ ha ⁻¹	mean	419.3 d	416.8 d	427.6 c	360.4 f	338.7 h	344.5 g	365.6 e	525.0 b	530.9 a
C	t ha ⁻¹	mean	222.2 c	222.1 c	223.5 b	206.9 e	200.5 f	200.6 f	208.4 d	256.3 a	256.4 a
DSP	-	P10	1.01 d	1.01 d	1 f	1.03 c	1.03 c	1.01 de	1.18 a	1.01 ef	1.05 b
		P50	1.15 d	1.16 d	1.09 f	1.21 c	1.21 c	1.11 ef	1.82 a	1.13 e	1.32 b
		P90	1.97 de	2 d	1.81 f	2.08 c	2.06 c	1.79 f	2.93 a	1.94 e	2.15 b
DSI	-	P10	2.65 b	2.66 b	2.65 b	2.69 a	2.7 a	2.69 a	2.7 a	2.57 d	2.59 c
		P50	2.7 c	2.7 c	2.69 d	2.74 a	2.74 a	2.72 b	2.73 a	2.62 f	2.65 e
		P90	2.73 d	2.73 d	2.73 d	2.76 bc	2.77 a	2.75 c	2.76 b	2.65 f	2.68 e
BHQ	%	poor	9.2 cd	8.7 cd	9.8 c	13.1 b	12.8 b	16.4 a	16.8 a	7.2 d	14.1 b
		medium	39.9 NA	36.7 NA	41.8 NA	41.8 NA	45.1 NA	45.6 NA	51.3 NA	37.4 NA	55.0 NA
		good	50.9 b	54.9 a	48.4 b	45.1 c	42.1 d	38.1 e	31.9 f	55.4 a	30.9 f
API	-	P10	0.77 bc	0.80 b	0.78 b	0.77 bc	0.72 c	0.76 bc	0.77 bc	0.85 a	0.81 ab
		P50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LPI	%	poor	5.9	5.5	5.3	5.9	6.1	6.1	4.7	4.3	4.2
		medium	24.1 e	23.8 e	30.3 c	29.0 d	31.0 bc	43.0 a	32.0 b	20.0 f	18.0 g
		good	70.5 c	70.3 c	64.4 de	65.4 d	62.4 f	51.1 g	63.0 ef	75.9 b	77.9 a
RPI	-	P10	0.63 c	0.65 c	0.56 d	0.54 d	0.5 e	0.45 f	0.55 d	0.88 b	0.97 a
		P50	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
		P90	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Tab SM4-7 Ecosystem service indicators for management types under climate change (c5) in assessment period P3 (2067-2100), P10, P50, P90 = 10th, 50th, and 90th percentile, mean results of 10 simulation runs, Tukey tests for significant differences between management scenarios under climate change conditions (c5), letters denote significant (alpha = 0.05) differences between management scenarios, NA = excluded from test

Indicator	Unit		SLIT-LO	PATCH-LO	STRIP-LO	SLIT-HI	PATCH-HI	STRIP-HI	STRIP-HI-P	NOM	SAN
THV	m ³ ha ⁻¹ yr ⁻¹	mean	2.2 e	2.1 e	1.8 f	2.2 d	2.7 c	3.1 b	3.2 a	0.0 NA	0.0 NA
VI	m ³ ha ⁻¹ yr ⁻¹	mean	5.8 f	5.9 e	6.3 c	6.2 d	6.2 c	6.5 b	6.7 a	5.4 h	5.5 g
BBD	m ³ ha ⁻¹ yr ⁻¹	mean	2.7 b	2.7 b	2.7 b	2.4 c	2.2 d	2.2 d	1.9 e	3.1 a	3.1 a
V	m ³ ha ⁻¹	mean	354.7 bc	351.6 c	357.1 b	301.4 e	280.3 f	283.5 f	308.2 d	455.9 a	457.8 a
C	t ha ⁻¹	mean	207.3 c	206.8 c	207.4 c	192.9 e	186.6 f	186.8 f	195.3 d	240.2 b	242.7 a
<i>DSP</i>	-	P10	1.01 d	1.01 d	1.00 d	1.02 c	1.03 c	1.01 d	1.19 a	1.00 d	1.06 b
		P50	1.14 de	1.15 d	1.09 f	1.19 c	1.19 c	1.10 f	1.86 a	1.12 e	1.37 b
		P90	2.03 ef	2.04 de	1.90 g	2.08 cd	2.08 c	1.91 g	3.04 a	1.98 f	2.24 b
<i>DSI</i>	-	P10	2.67 d	2.68 c	2.68 cd	2.72 a	2.72 a	2.71 b	2.71 ab	2.59 f	2.63 e
		P50	2.72 d	2.73 d	2.72 d	2.75 a	2.75 ab	2.74 c	2.75 b	2.64 f	2.68 e
		P90	2.75 cd	2.75 c	2.75 d	2.77 ab	2.78 a	2.77 b	2.77 b	2.67 f	2.71 e
<i>BHQ</i>	%	poor	10.5 d	10.0 de	11.5 d	14.5 c	16.0 bc	18.7 a	17.3 ab	7.8 e	14.8 c
		medium	34.6 NA	34.0 NA	38.2 NA	41.7 NA	44.8 NA	46.5 NA	49.7 NA	28.4 NA	46.6 NA
		good	55.0 b	56.1 b	50.3 c	43.8 d	39.2 e	34.8 f	33.1 f	63.8 a	38.6 e
API	-	P10	0.70 bc	0.73 b	0.69 bc	0.74 b	0.70 bc	0.67 c	0.71 bc	0.79 a	0.71 bc
		P50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LPI	%	poor	6.5	6.1	6.3	6.1	6.8	8.3	5.2	5.1	4.6
		medium	34.7 d	36.9 cd	37.8 c	38.0 c	42.0 b	49.7 a	39.0 c	25.3 e	21.0 f
		good	58.8 c	57.0 cd	55.9 d	55.9 d	51.2 e	42.0 f	55.8 d	69.6 b	74.5 a
RPI	-	P10	0.48 c	0.49 c	0.43 d	0.41 d	0.36 e	0.34 e	0.44 d	0.67 b	0.76 a
		P50	0.99	0.99	0.99	0.96	0.93	0.92	0.99	0.99	0.99
		P90	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Tab SM4-8 Tukey tests for significant differences between climate change scenarios in period P3 for each management alternative; letters denote significant differences. n.s. = results not significant. For empty fields ANVOA/Tukey tests where not applicable because at least one group showed no variation.

Management	Climate	TVH	VI	BBD	V	C	DSP			DSI			BHQ		API			LPI		RPI		
		mean	mean	mean	mean	mean	P10	P50	P90	P10	P50	P90	poor	good	P10	P50	P90	poor	good	P10	P50	P90
SLIT-LO	c0	b	c	e	b	b		d	e	bc	b	b	n.s.	b	a			bc	c		bc	
	c1	a	ab	d	a	a		c	d	d	d	d	n.s.	b	ab			c	a		a	
	c2	d	c	c	e	e		c	c	ab	b	b	n.s.	b	bc			ab	d		d	
	c3	b	a	c	c	c		b	c	d	d	d	n.s.	b	bc			c	ab		ab	
	c4	c	b	b	d	d		a	b	c	c	c	n.s.	b	c			bc	bc		c	
	c5	e	d	a	f	f		b	a	a	a	a	n.s.	a	d			a	e		e	
PATCH-LO	c0	a	c	e	b	a		d	e	bc	b	b	ab	d	a			b	b		ab	
	c1	a	b	d	a	a		c	d	d	d	d	ab	cd	ab			b	a		a	
	c2	d	c	c	e	d		c	c	b	b	b	b	bc	b			b	c		c	
	c3	b	a	c	c	b		ab	c	d	d	e	b	bc	b			b	a		ab	
	c4	c	ab	b	d	c		a	b	c	c	c	ab	ab	b			b	ab		b	
	c5	e	d	a	f	e		b	a	a	a	a	a	a	c			a	d		d	
STRIP-LO	c0	a	c	e	b	a		c	e	a	b	a	ab	c	ab			b	abc		b	
	c1	a	b	d	a	a		b	d	d	e	c	c	bc	b			b	ab		ab	
	c2	c	c	c	d	d		b	c	b	c	b	ab	b	b			b	c		c	
	c3	a	a	c	b	b		a	c	e	f	d	bc	b	a			b	a		a	
	c4	b	b	b	c	c		a	b	c	d	c	bc	ab	b			b	bc		b	
	c5	d	d	a	e	e		a	a	a	a	a	a	a	c			a	d		d	
SLIT-HI	c0	a	b	e	b	b		d	d	b	a	a	cd	n.s.	a			ab	b		a	
	c1	a	a	d	a	a		c	c	d	d	c	d	n.s.	ab			ab	a		a	
	c2	d	b	c	d	d		c	c	b	b	b	ab	n.s.	bc			ab	c		b	
	c3	b	a	c	b	b		a	b	d	d	d	bcd	n.s.	cd			b	a		a	
	c4	c	a	b	c	c		a	a	c	c	c	abc	n.s.	cd			a	b		a	
	c5	e	c	a	e	e		b	a	a	a	a	a	n.s.	d			a	d		c	
PATCH-HI	c0	ab	c	e	b	b		d	d	b	a	b	bc	a	a			ab	b		b	
	c1	a	b	d	a	a		c	c	d	c	d	c	ab	ab			bc	a		ab	
	c2	d	c	c	d	d		c	c	bc	b	c	ab	bc	ab			ab	b		c	
	c3	b	a	c	b	b		a	b	d	c	e	bc	ab	ab			c	a		a	
	c4	c	b	b	c	c		a	ab	c	b	cd	bc	ab	ab			bc	b		ab	
	c5	e	d	a	e	e		b	a	a	a	a	a	c	b			a	c		d	
STRIP-HI	c0	a	c	e	c	b		c	e	b	a	a	b	b	a			b	bc		bc	
	c1	a	b	d	a	a		b	d	c	c	c	b	a	a			bc	ab		ab	
	c2	d	c	c	e	d		b	c	b	b	b	b	b	a			bc	c		c	
	c3	b	a	c	b	b		a	c	c	d	d	b	a	a			bc	a		a	
	c4	c	b	b	d	c		a	b	b	b	c	b	a	a			c	b		ab	
	c5	e	d	a	f	e		a	a	a	a	a	a	b	b			a	d		d	
STRIP-HI-P	c0	a	c	e	c	d	d	f	e	b	a	a	n.s.	n.s.	a			a	c		b	
	c1	a	b	d	a	a	c	e	d	d	cd	cd	n.s.	n.s.	b			abc	b		a	
	c2	d	c	c	d	e	c	d	c	b	b	bc	n.s.	n.s.	ab			bc	c		b	
	c3	b	a	c	b	b	b	c	c	d	d	e	n.s.	n.s.	a			bc	a		a	
	c4	c	a	b	c	c	ab	b	b	c	c	de	n.s.	n.s.	b			c	ab		a	
	c5	e	d	a	e	f	a	a	a	a	a	b	n.s.	n.s.	c			ab	d		c	
NOM	c0	NA	c	e	ab	a		e	e	b	b	b	a	d	a			b	ab		a	
	c1	NA	b	d	a	a		d	d	c	c	d	ab	c	ab			b	a		a	
	c2	NA	c	c	d	d		c	c	a	a	b	a	c	ab			b	c		b	
	c3	NA	a	c	b	b		b	c	c	c	e	ab	c	a			b	abc		a	
	c4	NA	ab	b	c	c		a	b	b	b	c	b	b	b			b	bc		b	
	c5	NA	d	a	e	e		a	a	a	a	a	ab	a	c			a	d		c	
SAN	c0	NA	c	e	ab	ab		e	e	c	d	d	b	b	a			b	a		a	
	c1	NA	b	d	a	a		d	d	c	d	e	a	bcd	ab			b	a		a	
	c2	NA	c	c	d	d		c	c	b	b	b	ab	bc	b			b	b		b	
	c3	NA	a	c	b	b		c	c	c	d	de	a	cd	b			b	ab		a	
	c4	NA	b	b	c	c		b	b	b	c	c	a	d	b			b	ab		a	
	c5	NA	d	a	e	e		a	a	a	a	a	a	a	c			a	c		c	