Landcare Research
Manaaki Whenua

Guidelines for Monitoring Land Fragmentation

Envirolink Tools Project 2013-2014

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Land Monitoring Forum Meeting

Blenheim, 29-30 Aug 2013

Today's Agenda

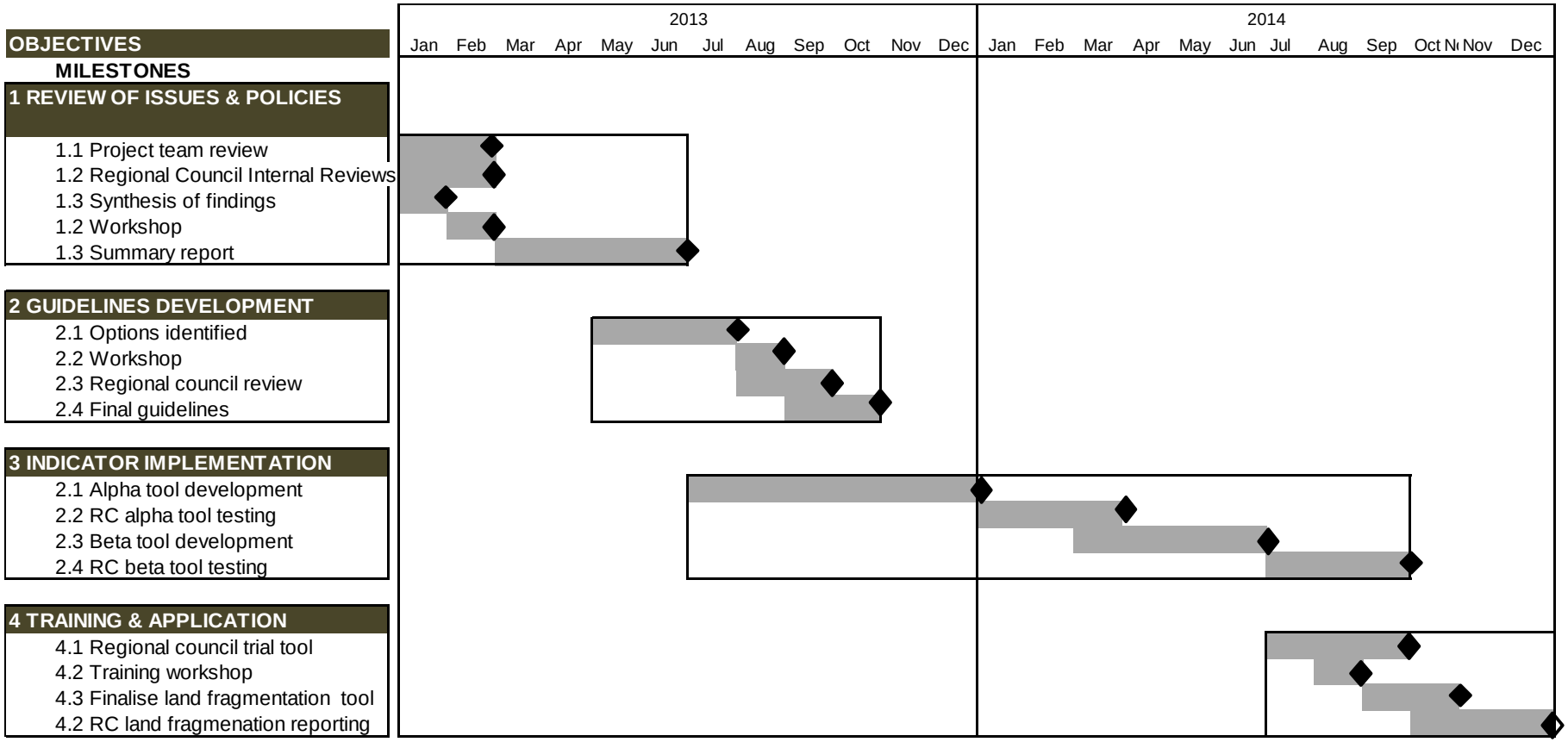
- Quick recap on Land Fragmentation Guidelines Project

- Update on Stage One: Results of the review of current knowledge and issues
- Update on Stage Two: Initial review of land fragmentation indicators

Land Fragmentation Project Overview

- Objectives
  - Develop national guidelines and methodologies for measuring land fragmentation trends over time.
  - Develop a tool to assist regional councils with processing and analysing data to monitor and report on land fragmentation trends.
  - Train regional councils in tool use and generate a set of first generation reports for each participating region.
- 2 Years (Jan 2013 – Dec 2014)

Project Schedule



Objective 1: Review of issues and policies

- The aim of stage one was to review the state of knowledge, policies and monitoring of land fragmentation in New Zealand

- Results of the national questionnaire with regional councils

Objective 2: Guidelines development

- The aim of the second stage is the development of guidelines and methodologies for monitoring of land fragmentation in New Zealand

- Results of an initial review of indicators used in land fragmentation research

Land Fragmentation Questionnaire

- Aim: To assess current state of knowledge on land fragmentation and responses at regional councils
- Four parts:
  1) Background information
  2) Issues
  3) Policies, plans, rules and consenting
  4) Information, data and monitoring
- District and city council responses

Land Fragmentation Questionnaire: Results

- Part A: Background information
- Part B: Issues:
  1. Definitions
  2. Regional importance
  3. Relative rank
  4. Key drivers
  5. Hotspots

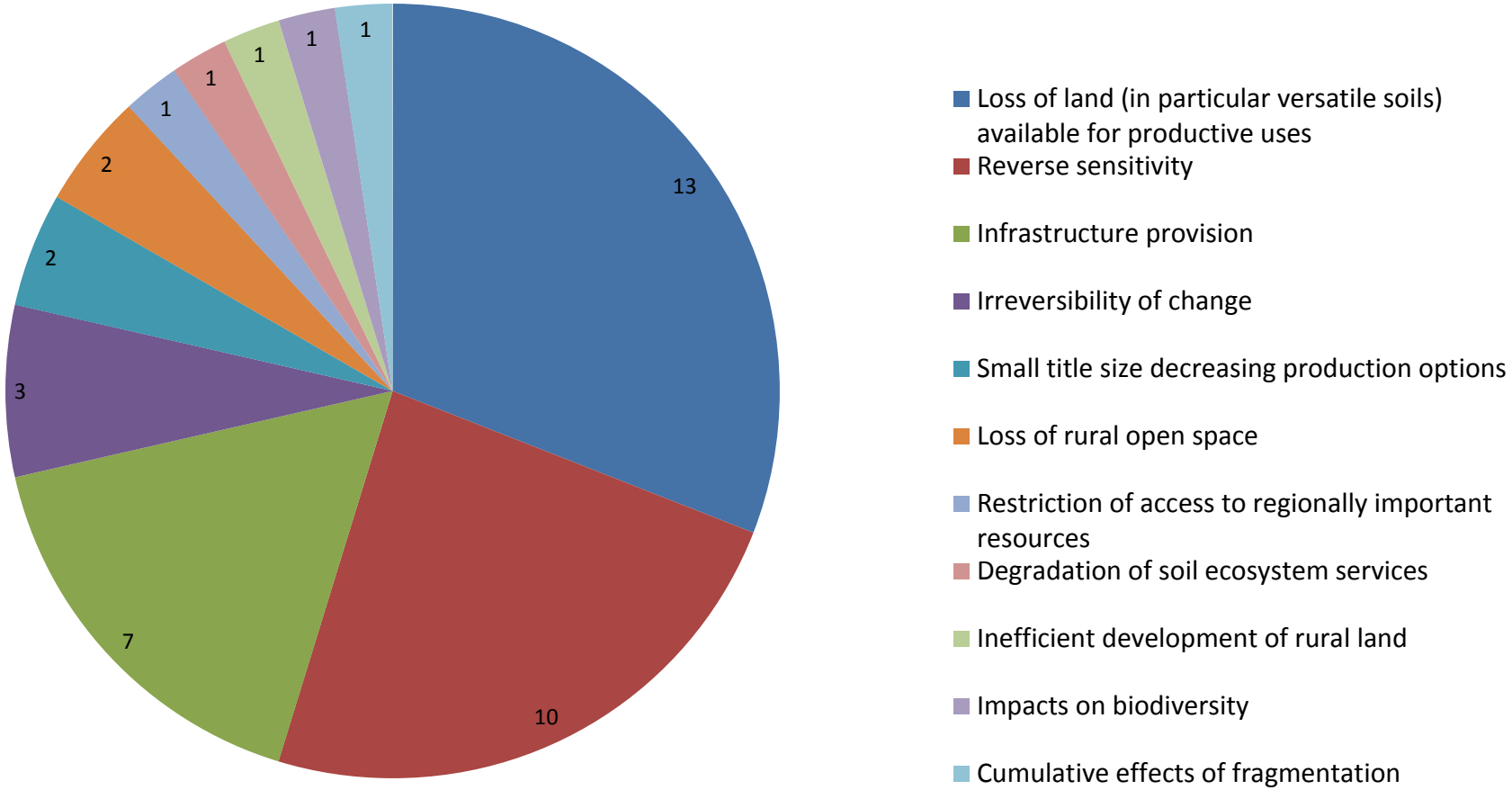
Results: Issues – Land fragmentation definitions

Land fragmentation is an accepted and utilised term in both the planning and operational teams within the Auckland Council – and in a variety of land use contexts (rural and urban)…it occurs when large land parcels used for agriculture are subdivided into small and more intensive production units, hobby farms, or lifestyle blocks primarily for residential use. Rural fragmentation increases settlement density and also excludes land uses such as pastoral farming that, for practical or economic reasons, require large land parcels.

Results: Issues – Importance and rank

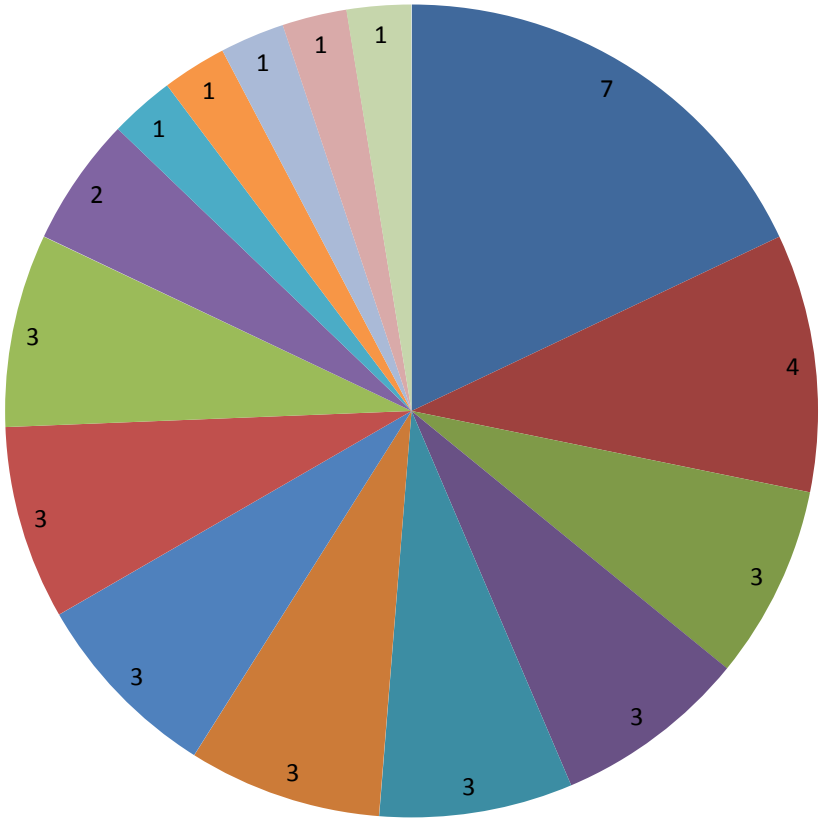
Regional Council or Unitary Authority	Importance of Land Fragmentation	Relative Rank (Low, Medium, High)	Higher Ranking Issues (if present)
Northland	Important	Medium to low	Water quality, natural hazards, infrastructure provision
Auckland	Important	Medium to high	Housing affordability, transport, growth management
Waikato	Important	Medium to low overall (medium to high soil issue)	Water quality, waste disposal, air pollution, general pollution, transport, erosion
Bay of Plenty	Important	High	No answer
Gisborne	Important	High	Hill country soil erosion
Hawke's Bay	Not important regionally, locally important	Medium to low – rest of region	Urban planning, infrastructure planning
		High – Heretaunga plains	
Taranaki	Not important	Low	Soil issues: accelerated erosion, soil compaction, soil nutrient depletion, and water quality
Manawatu-Wanganui	Not important	Low	Water allocation, water quality, hill country erosion and indigenous biodiversity
Wellington	Not important	Low	Water quality, soil erosion
Nelson	Not important	Low	Natural hazards, Intensification, service provision, climate change, urban design
Marlborough	Not important regionally, locally important	Medium	Water allocation, landscapes, biodiversity, and water quality
West Coast	Not important	Low	Water quality, natural hazards
Tasman	Important	High	No answer
Canterbury	Not important	Low	No answer
Otago	Important	Low	Water and air management
Southland	Not important	Low	Water quality

Results: Issues – Land fragmentation impacts



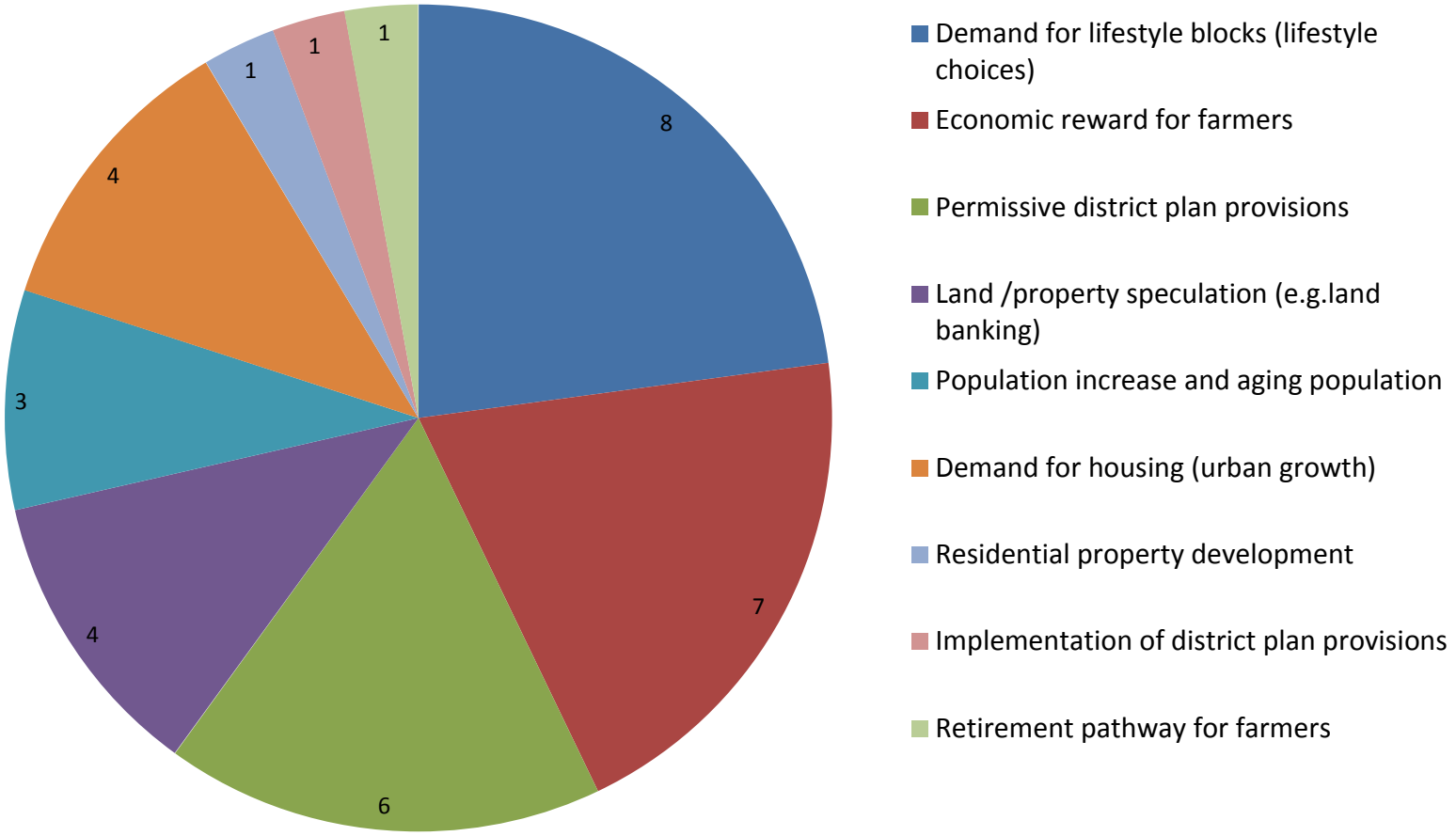
Key issues regarding land fragmentation and frequency identified by regional councils in New Zealand

Results: Issues – Land fragmentation impacts



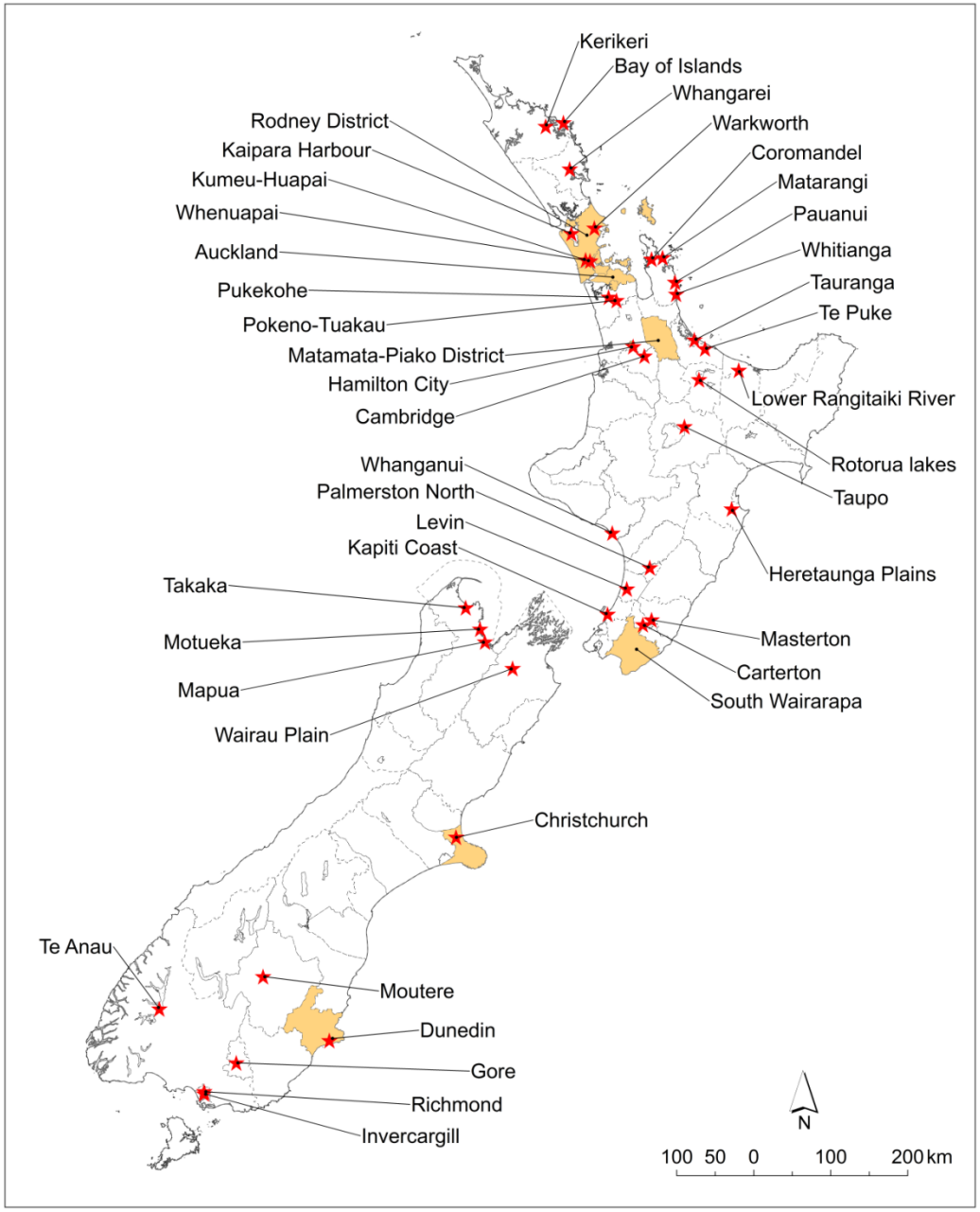
Issues related to land fragmentation and frequency identified by regional and unitary councils

Results: Issues – Drivers of land fragmentation



Land fragmentation drivers and frequency identified by New Zealand councils

Results: Issues



Land fragmentation hotspots

Results: PART C Policies, Plan, Rules, Consents

CASE STUDY: TASMAN DISTRICT COUNCIL

ISSUE: cumulative effects of development of rural land for non-soil-based purposes on: *i) the life-supporting capacity of soil, water and ecosystems in rural areas; (ii) the availability of land for soil and other natural resource-based production opportunities for the well-being of present and future generations; (iii) service provision, site amenity, contamination and natural hazard risk, and on heritage and landscape values*

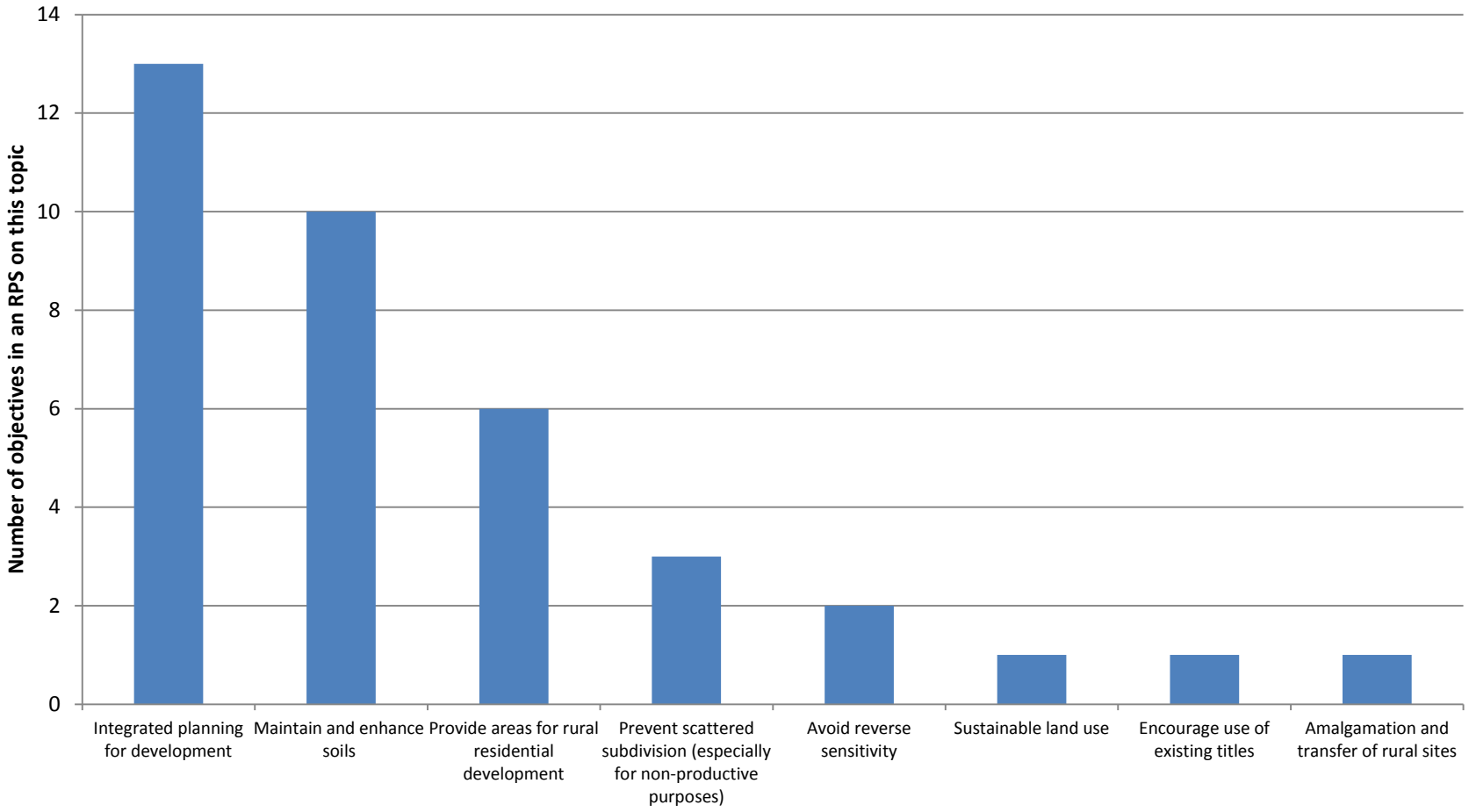
OBJECTIVES: avoid any further loss of productive land for purposes other than soil based production; to provide for the non-soil-based use of rural land while avoiding loss of productive land; and to avoid conflicts between competing uses of the land resource.

POLICIES: 8 policies are set to address rural land use issues and the loss of versatile soils. These include: managing the rural land resource to avoid the loss of productive land due to subdivision, or other non-soil-based activities; ensuring land parcels are of a size and shape that retains productive potential of the land, subdivision size and shape must also give consideration to land's versatility, ecosystems, cross-boundary effects, access and ability to service the title; facilitating title amalgamation and relocation of boundaries; protecting natural resources of regional importance, e.g. hard rock quarry resources; and in particular regard to the Takaka-Eastern Golden Bay area that rural-residential subdivision and development is discouraged.

METHODS: Regulatory: zoning, with parcel size, activity status, and setback rules for the different zones; guidance for decision makers when considering resource consent decisions.

Non-regulatory: monitoring of the number and size of rural land titles and uses of rural land.

Results: Policies, Plan, Rules, Consents



Results: PART D - Information, data and monitoring

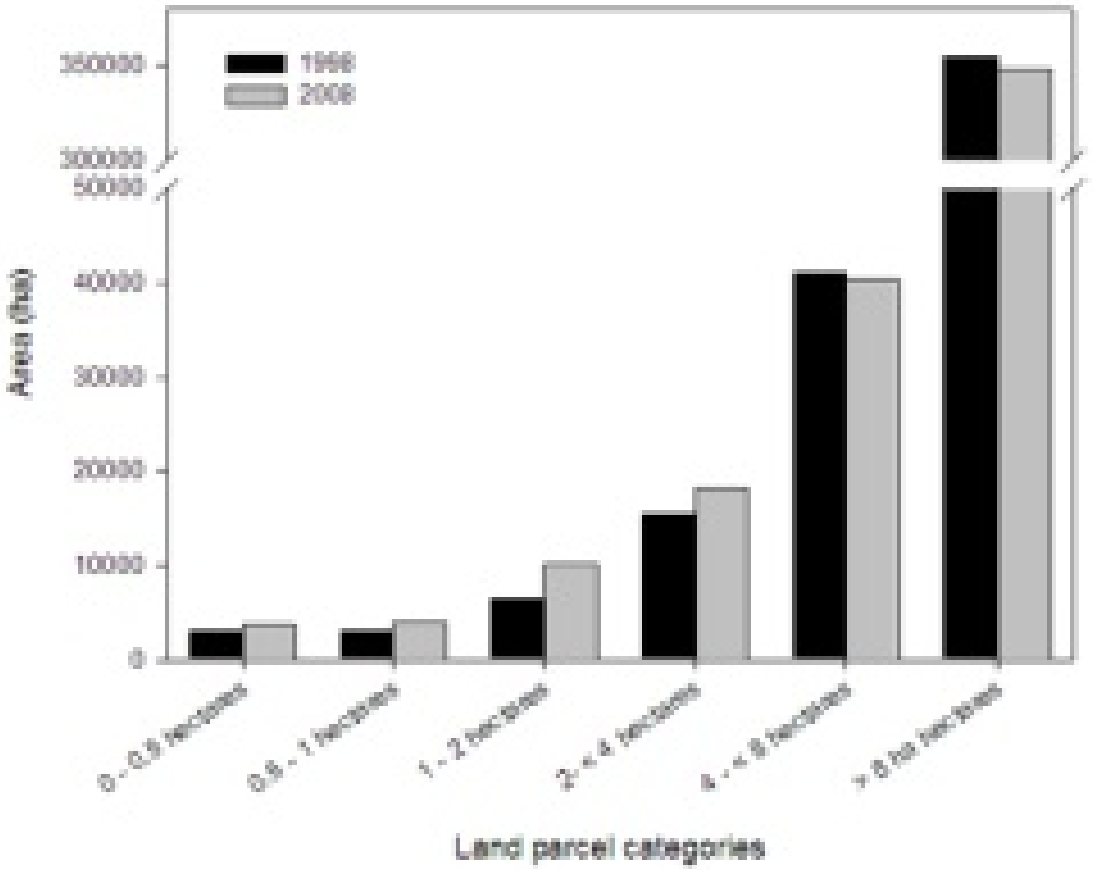
Monitoring

- 3 councils monitor and report on land fragmentation – Auckland, Waikato Marlborough
- Others report occasionally
- Several others are committed to establishing monitoring of land fragmentation (or similar)

Results: Information, data and monitoring

Council	Monitor	Data used
Auckland	Δ size and number of land parcels outside of the Metropolitan Urban Limit (MUL) Δ number of vacant titles	Land parcel data - from the Digital Cadastral Database (DCDB) LINZ.
Waikato	Δ subdivision of low-density rural land	Census meshblock data (can show where land available per dwelling has decreased below 4ha) LUC classification data
Marlborough	Δ number of titles (possible Δ size of titles)	District consents database
Matamata-Piako District	Applications received/granted to subdivide LUC I, II and III land below 8 ha Area of LUC I, II, III land removed from the rural zone through DP changes Average lot size for rural subdivision on LUC class I, II and III land # lots 2500m^2-10,000m^2 # subdivisions declined for subdivision on class I, II and III land	District consents database LUC classification data

Example: Auckland reporting



Number of land parcels by size (hectares), 1998 and 2008. (Source: Landcare Research and ARC). Accessed from: http://monitorauckland.arc.govt.nz/natural-environment-and-heritage/land-management/rural-fragmentation.cfm

Results: Information, data and monitoring

Information – requests and comments

- Better quality land use information: Aerial photography, remote sensing, ground truthing
- Better quality data of high quality land
- Definitions and consistency: land fragmentation, high quality soils, monitoring methods
- Indicator of LUC I, II and III land lost of non-productive use each year
- Indicators of other impacts – environment pressures, social and economic
- More cross organisational co-operation and sharing

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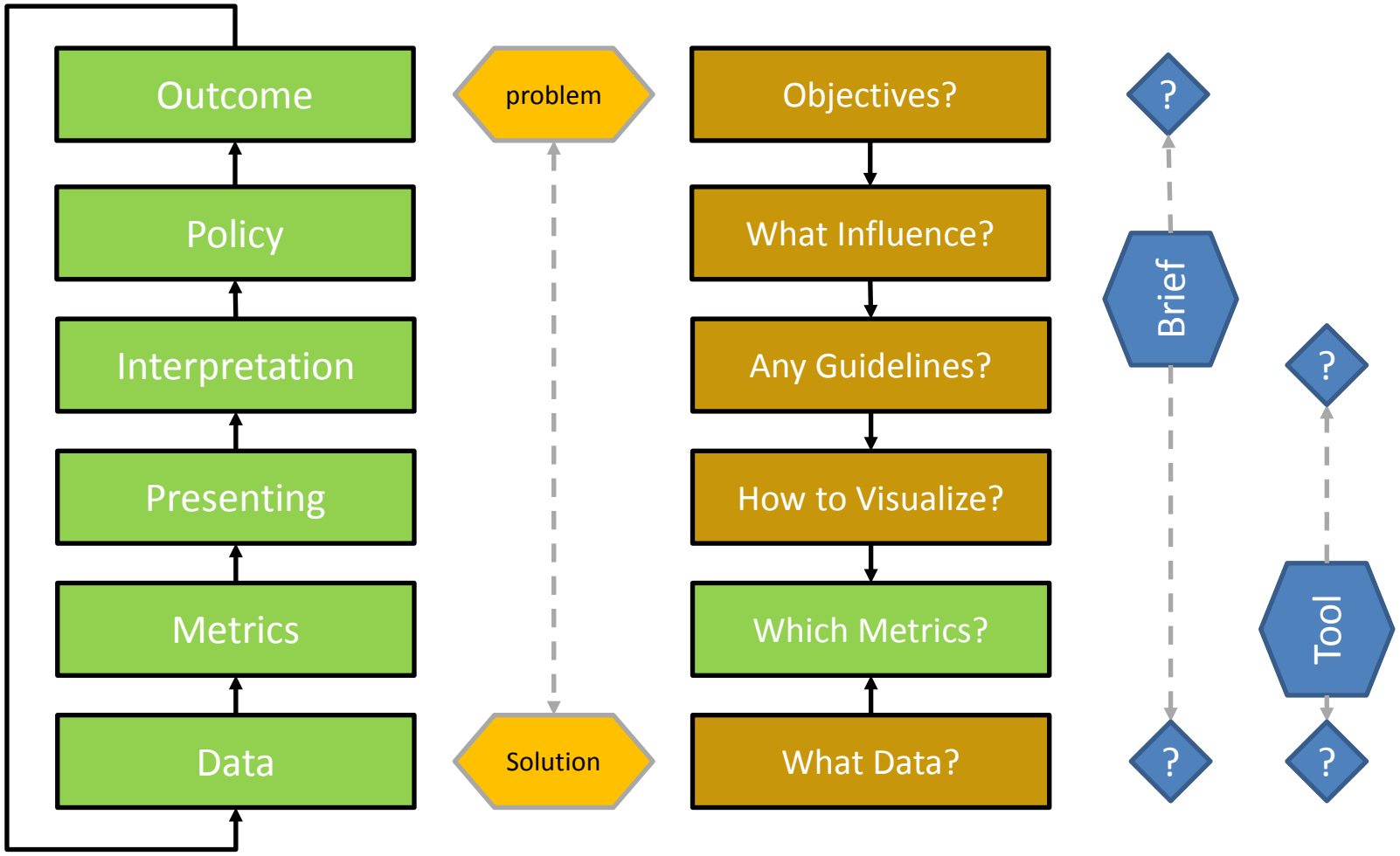
Fragmentation Metrics

Robbie Price

Some additional information for the Presentation to LMF (information, diagrams etc not in Literature Review – though papers used are)

Defining Solution Space



Metrics and Policy

- Need to determine what policy decisions the metrics will be informing:
  - Identifying Current Issues
  - Identifying Potential Issues
  - Property Level / Landscape level
  - What scale of knowledge
    - Property/Enterprise/Landscape/Regional…

Interpreting Metrics

- What can gleaned from a given metric
  - Guidelines for use and interpretation
- Metrics values are generally scale dependent.
  - Values determined by data resolution
  - Only comparable when data resolution same
  - Determine the scale-value relationship?
- Consistency over time

Presenting Metrics

- Single Figure
  - Landscape Level
- Table
  - Patch or Class Level
- Graphs
  - Patch /Class Level
- Maps
  - Cell / Patch /Class Level
- Frequency and Extent of generation

Single Figure

•Example of landscape level metrics presented within table (after Austin *et al*. 2012)

	Minimum	Maximum	Mean	Standard deviation	Variance
Output/ha	3504	93857	32482	18648	3.478E8
Age	27	60	48.98	6.44	41.40
Household size	1	10	6.41	1.54	2.37
Education	0	18	7.90	4.43	19.61
Farming Experience	2	35	17.54	5.18	26.80
Fragmentation Index	0.01	1.00	0.55	0.15	0.02
Labour	17	31.50	54.59	31.72	1006.24
Duration of tenure	30	99	52.59	9.95	99.05
Capital	450	8500	102472	719.25	517313.83
Distance	2	35	3.55	3.01	9.03
Farm size	0.3	5.2	2.68	1.23	1.520

Graph-able Index

- In this instance calculated for each owner
  - (Demetriou 2012)

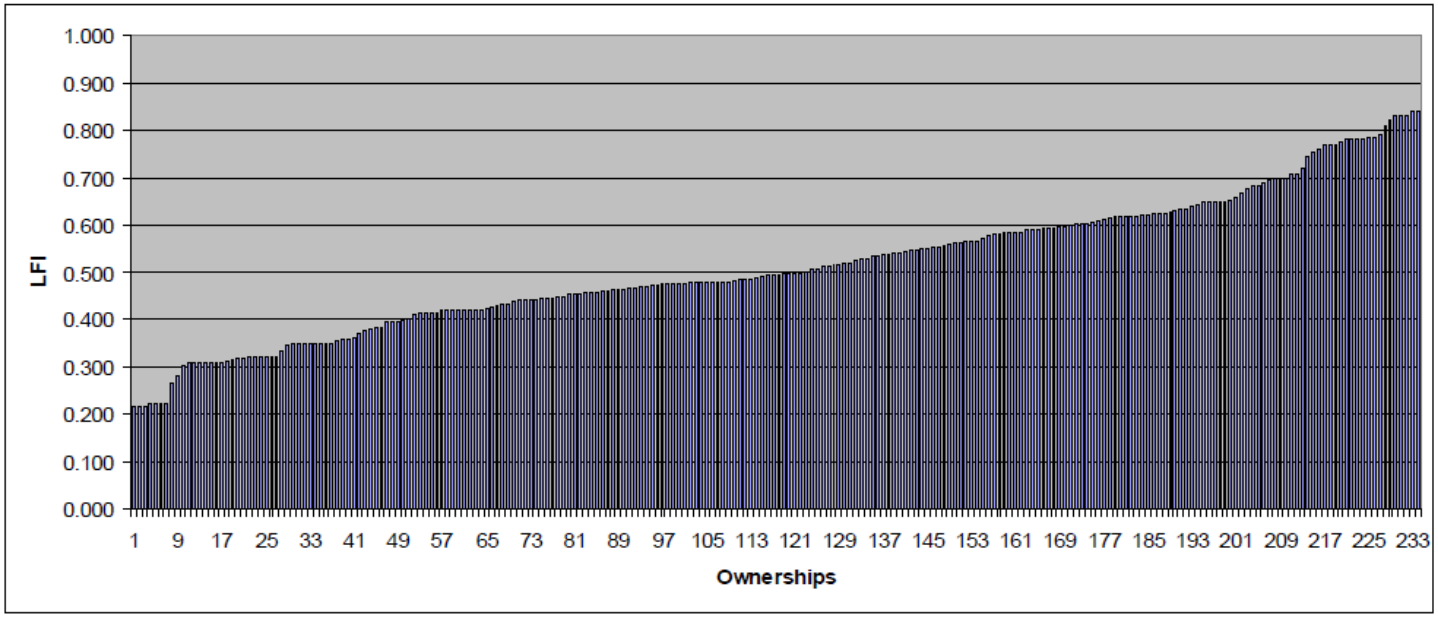


Figure 7: Distribution of the new LFI index across holdings

Mapped Metrics

- Spatially defined types of measures can be shown on maps as well as presented graphically
  - From Inostrosa *et al*. (2013)

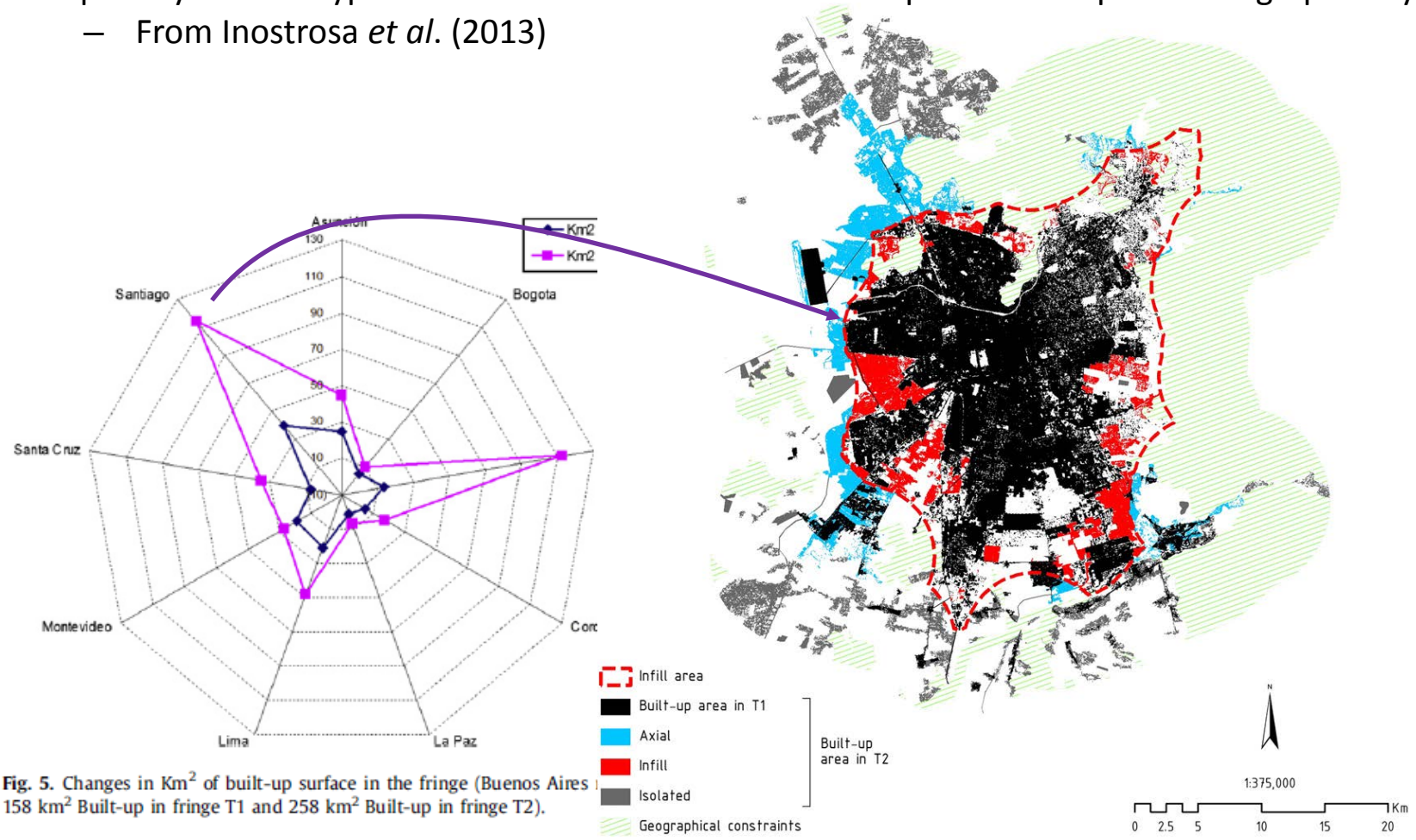
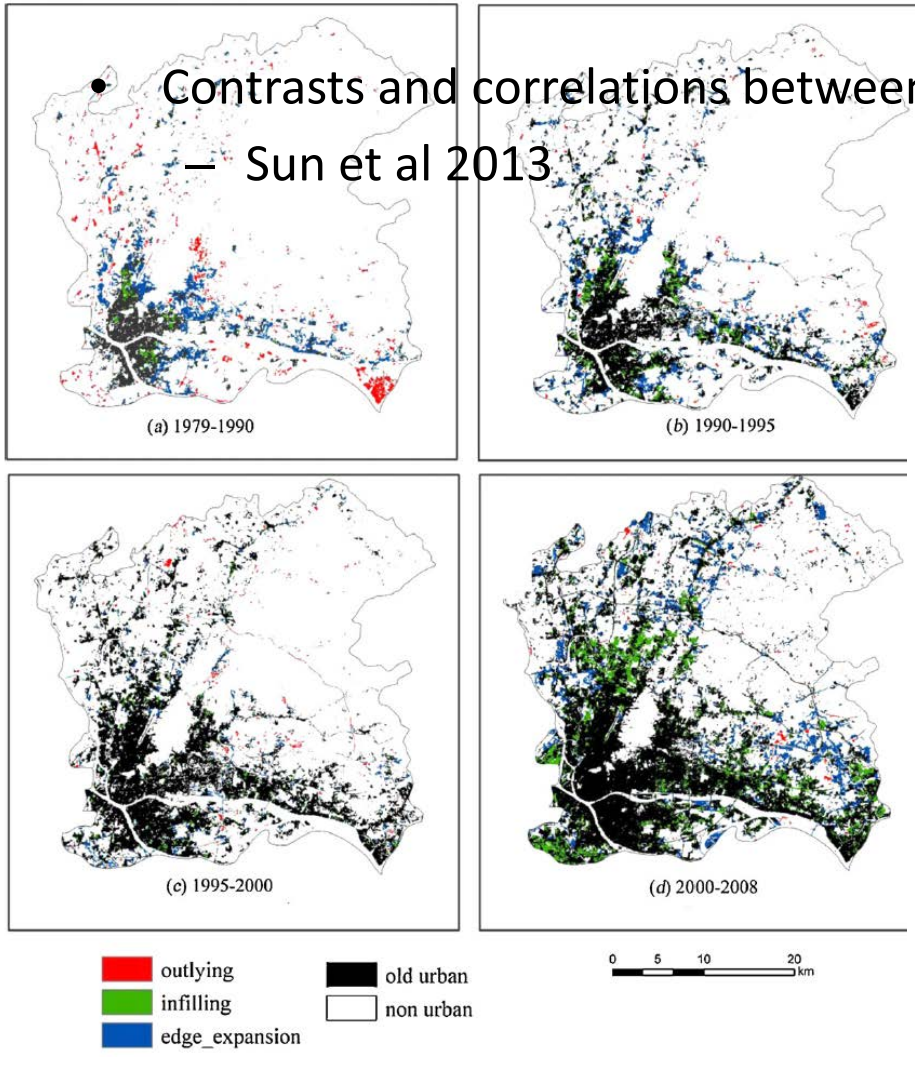


Fig. 5. Changes in Km^2 of built-up surface in the fringe (Buenos Aires
158 km^2 Built-up in fringe T1 and 258 km^2 Built-up in fringe T2).

Multiple Metrics and Time

- Contrasts and correlations between metrics
  - Sun et al 2013



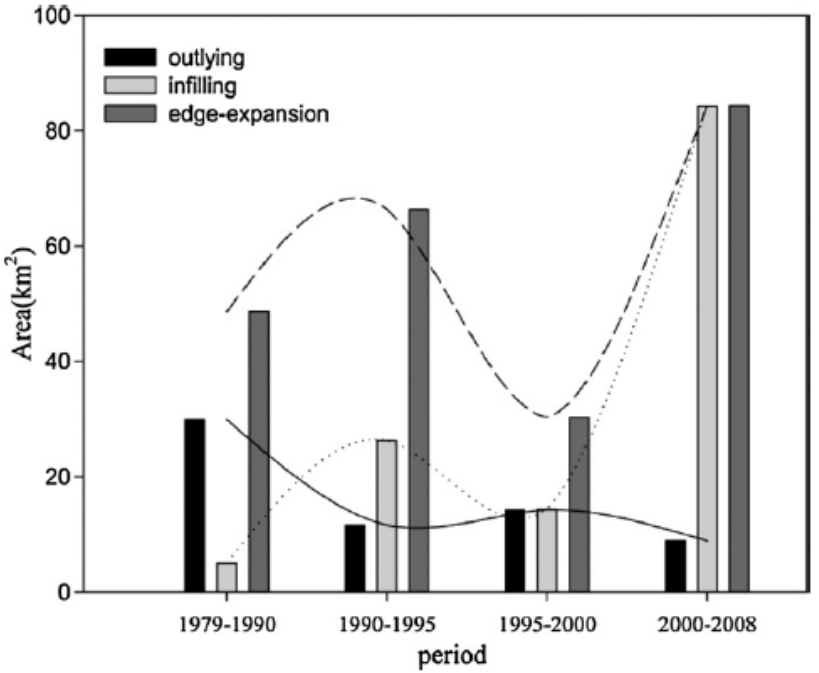


Fig. 5. Area of three urban growth types during the four periods 1979–1990, 1990–1995, 1995–2000 and 2000–2008.

Multiple Metrics

- Different metrics tell slightly different stories
- Strongly correlated metrics can become redundant, or can identify subtleties

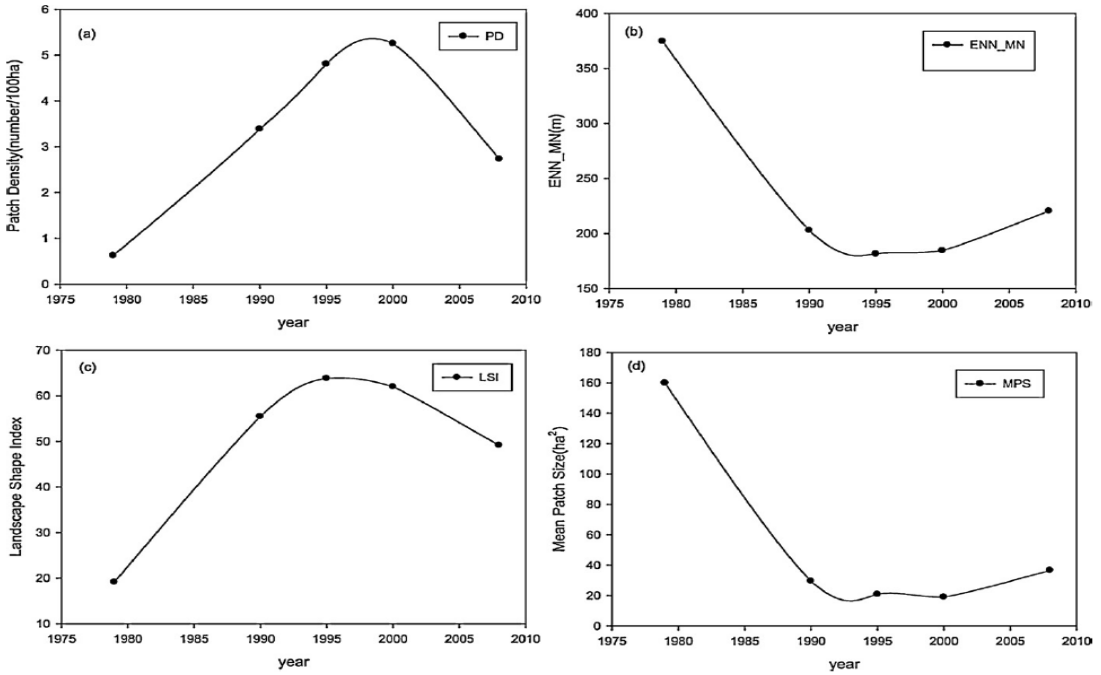
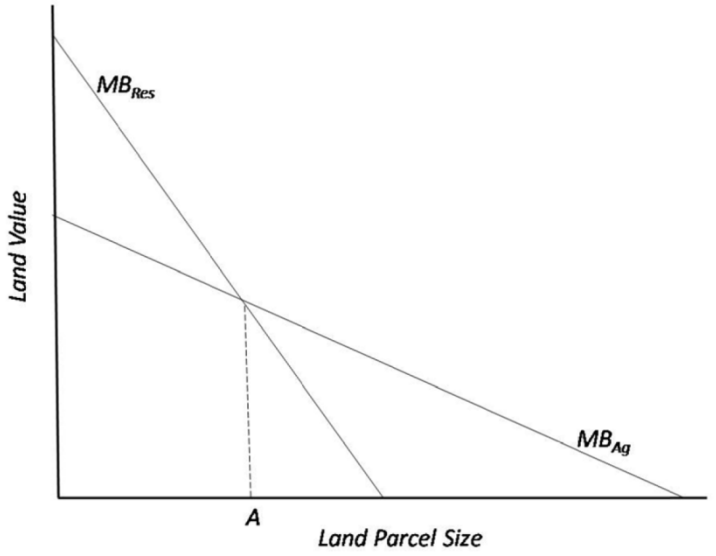


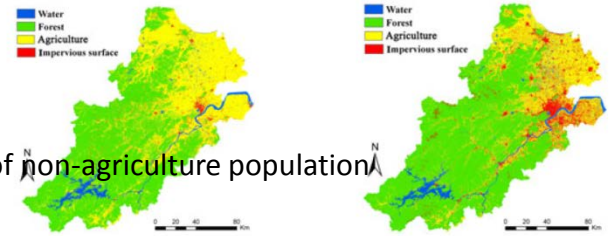
Fig. 6. Spatial metrics of Guangzhou during the period 1979–2008: (a) Patch density (PD); (b) Euclidean Nearest-Neighbor Distance (ENN); (c) Landscape Shape Index (LSI); and (d) Mean Patch Size (MPS).

Different Disciplines

- Economics
  - From Versace *et al.*
  - Economic indicator of Marginal Benefit as driver for Land Use change



Urban vs Agriculture



- Urban (AIS, GDP, POP, UR)
- area of impervious surface, GDP per capita, total population, percentage of non-agriculture population
- Agricultural (TA, PD, AWMSI, ENND)
  - [Total Area, Patch Density, Area Weighed Mean Shape Index (Shape Index), Euclidean Nearest Neighbour Distance]
  - From Zou *et al*. (2011)

Table 1. Changes of urbanization indicators and agricultural landscape metrics between 1994 and 2008

	AIS	GDP	POP	UR	TA	PD	AWMSI	ENND
Hangzhou	314.8	226.3	12.6	24.2	-37.7	144.0	13.1	5.0
Fuyang	108.3	248.3	3.4	37.8	-44.0	21.6	-51.7	2.7
Lin'an	21.0	175.3	2.1	67.4	-51.4	76.2	-73.4	9.4
Jiande	115.1	212.4	3.1	32.3	-43.2	13.7	-53.0	4.4
Tonglu	91.6	252.9	1.6	47.7	-40.3	80.2	-49.8	-3.3
Chun'an	-20.1	268.7	1.3	50.5	-72.0	111.0	-46.1	14.7
Anji	224.0	186.1	0.7	61.7	-33.8	15.2	-8.3	2.5
Deqing	372.5	159.3	3.3	38.0	-31.9	57.9	97.2	6.0
Huzhou	508.9	167.3	3.0	202.6	-26.5	70.2	85.5	5.4
Changxin	152.3	134.9	1.6	44.5	-19.0	-36.5	85.7	2.9
Tongxiang	472.2	179.2	2.9	29.9	-12.7	681.2	244.8	12.5

Grain Size

- Index values dependent on resolution
  - Yang *et al.* 2012

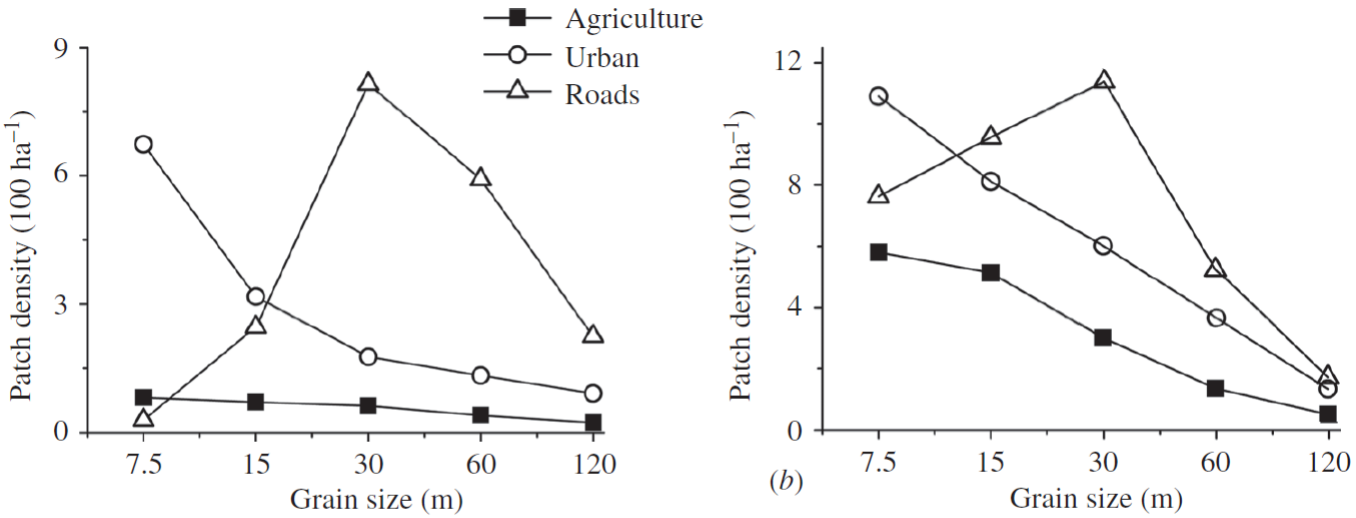


Figure 4. Class-level patch density (PD) in transects with changing grain sizes of 7.5, 15, 30, 60 and 120 m. (*a*) Shanghai city and (*b*) Zhangjiagang city.

Selection of Metrics

- Easy if one knows precisely what one is looking for
- Try them all
- Select the best
- Forget rest

Table 4 Factor analyses for metrics measuring the dense forest and metrics measuring the combination of dense and sparse forest. Factors were retained by the rule of eigenvalue > 1.0. Factor loadings > 0.8 are underlined, and factor loadings < 0.3 are not presented. Metrics in bold were selected for statistical analysis and model building. See Table 2 for a description of the landscape metrics.

Metrics measuring dense forest	Factor				Metrics measuring combination of dense and sparse forest	Factor			
	1st	2nd	3rd	4th		1st	2nd	3rd	4th
ED		0.92			**AREA**	0.94			
LPI	0.91				**ED**		0.95		
LSI	−0.46	0.79			LSI		0.49	0.72	
PD	−0.80				PD	−0.49	−0.56	0.41	
CONTIG	0.87				PLAND	0.68	0.43		
SHAPEX	0.73	0.42			CONTIG	0.81			
DCAD		0.74		0.31	SHAPE		0.80		
DCORE	0.61	−0.48			CPLAND	0.45			
ENN	−0.67				DCAD		0.71	0.38	
PROX				0.89	DCORE	0.62		−0.51	
SPLIT			−0.79		ENN	−0.60			−0.31
IJI		0.53			**PROX**		0.90		
CLUMPY			0.90		SPLIT			−0.76	
AI	0.75		0.53		IJI		0.68		
CONNECT				0.88	**CLUMPY**			0.86	
COHESION	0.56	0.35	0.63		AI		0.54		0.53
					CONNECT	0.49		0.81	
					COHESION		0.43		0.52
Eigenvalue	6.19	4.28	2.35	1.51	Eigenvalue	8.18	2.82	1.70	1.39
Percentage of variance	38.69	26.75	14.69	9.44	Percentage of variance	45.43	15.67	9.44	7.71
Percentage of cum. variance	38.69	55.44	70.13	79.57	Percentage of cum. variance	45.43	61.11	70.54	78.25

Extraction method: principal components analysis.
Rotation method: Varimax with Kaiser's normalization.

About Metrics

- An almost limitless number of metrics
- Based on a few key attributes of landscape (amount, shape, neighbours)
- Generally designed to be calculated on landscape scale not national scale
- No overriding theoretical framework
    - Design
    - Use
- No stable classification

Overview of Metrics

(All slides this colour From FRAGSTATS V4 manual – see draft report)

- Level
  - Data scale (not spatial scale) at which calculated
- Type/Aspect
  - Based on what attribute they measure
- Single dimension, categorical
  - One data layer, one attribute, no overlaps

Level

- Cell
  - computed for every cell in the landscape (Raster)
- Patch
  - computed for every patch in the landscape
- Class
  - Class metrics are computed for every patch type or class in the landscape
- Landscape
  - Landscape metrics are computed for entire patch mosaic

Type/Aspect

- Area and edge metrics
- Shape metrics
- Core area metrics
- Contrast metrics
- Aggregation metrics
- Diversity metrics

Area and Edge Metrics (p75)

- Metrics that deal with the size of patches and the amount of edge created by these patches.
- Area, Perimeter, Mean Patch Size etc.
- Fundamental information, detecting change, minimum areas etc.
- Simple stats such as total area, good for detecting area change

Shape metrics (p88)

- Complexity of patch shape, based on perimeter-area relationships, or by comparison to standard shapes.
- Perimeter-Area Ratio, Fractal Dimension Index
- Patch, Class, and Landscape
- Useful for detecting edge effects, but not inter patch interactions

Core area metrics (p96)

- Core area is defined as the area within a patch excluding some buffer.
- Core Area, Number of Core Areas
- Predictor of habitat quality by excluding areas of edge effect
- Simple interpretation of biological significant edge effects

Contrast metrics (p105)

- Contrast refers to the magnitude of difference between adjacent patch types
- Edge Contrast Index, Contrast-Weighted Edge Density
- Used to detect potential positive or negative inter-patch interactions

Aggregation metrics (p112)

- An umbrella term to describe several closely related concepts: Dispersion, Interspersion, Subdivision, Isolation.
- ENN (sic) Distance, Aggregation Index, Patch Density…
- Large number of metrics dealing with landscape heterogeneity and texture
- Complex interpretation good for issues like potential dispersal

Diversity metrics (152)

- Diversity measures of Richness (number of) and Eveness (size distribution of) of a landscape
- Patch Richness, Shannon's Diversity Index, Simpson's diversity index, Shannon’s Evenness Index…

Other Metrics

- FRAGSTATS not comprehensive
- Januszewski index
  - Size distribution
  - Fine scale analysis of property ownership
- Combinatorial Analysis
  - Multi-dimensional, pseudo-spatial (Area metrics only)
  - NZ Threatened Environments Classification
- “Invent Your Own” – totally valid

Calculating Metrics

- Metrics platform and software specific
  - FRAGSTATS (requires ESRI libraries)
  - R [SDMTools]
    - Bio7 (requires R)
- Metrics require different types of data
  - Only consider metrics for which required data is available

Summary: Working Backwards

- Start from the end users perspective
- Who are they?
- What do they need a metric for?
- How will it be interpreted?
  - Quantitative, Qualitative
- How should that metric be presented?
  - Figures, Tables, Graphs, Maps
- How to Calculate?
- What data is required?