"The Empowerment of Local Authorities: Spatial Information and Spatial Planning Tools
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LandSpaCES*: A Spatial Planning Tool for Land Consolidation

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(LandSpaCES*= Land Spatial Consolidation Expert System)

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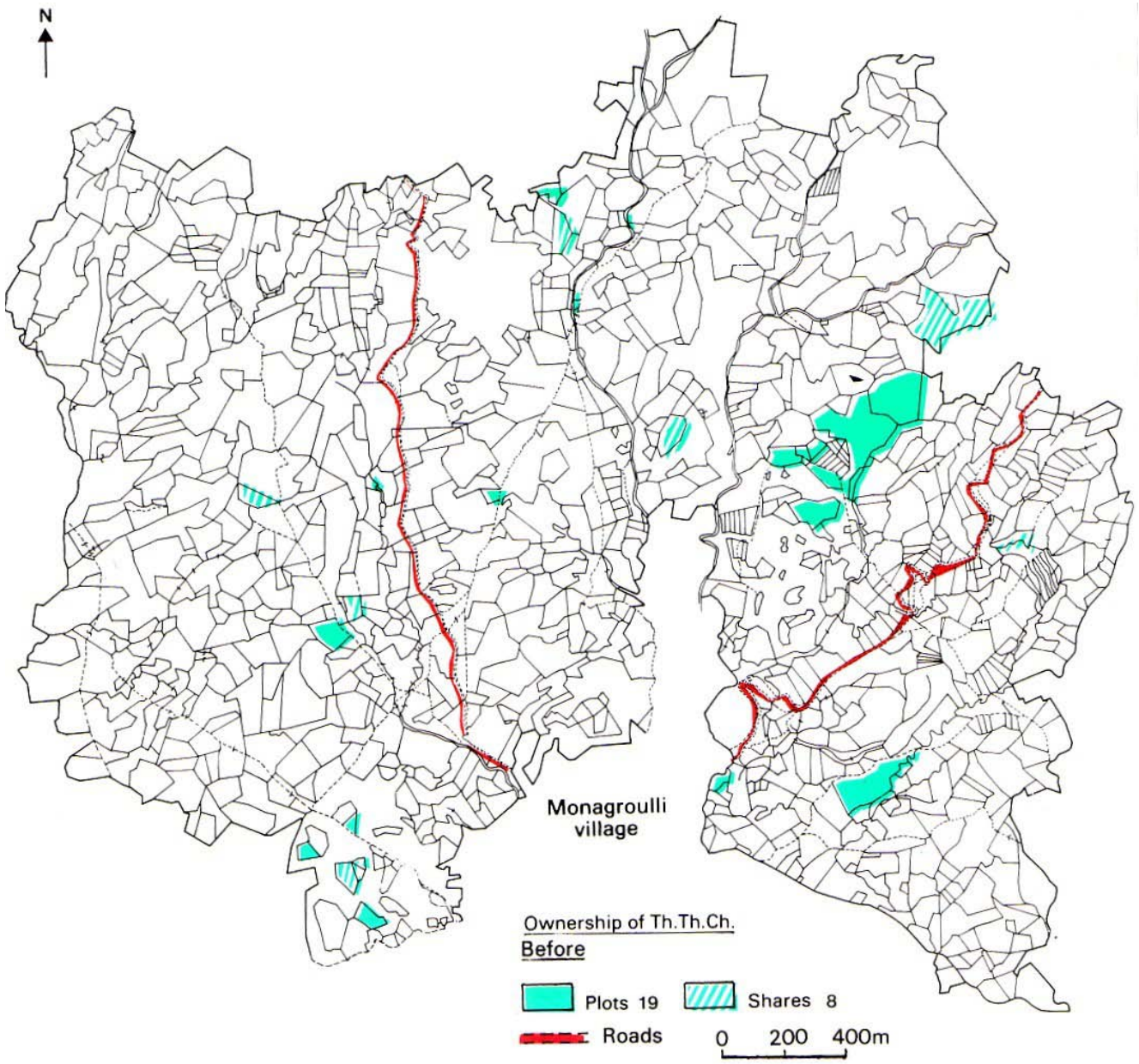
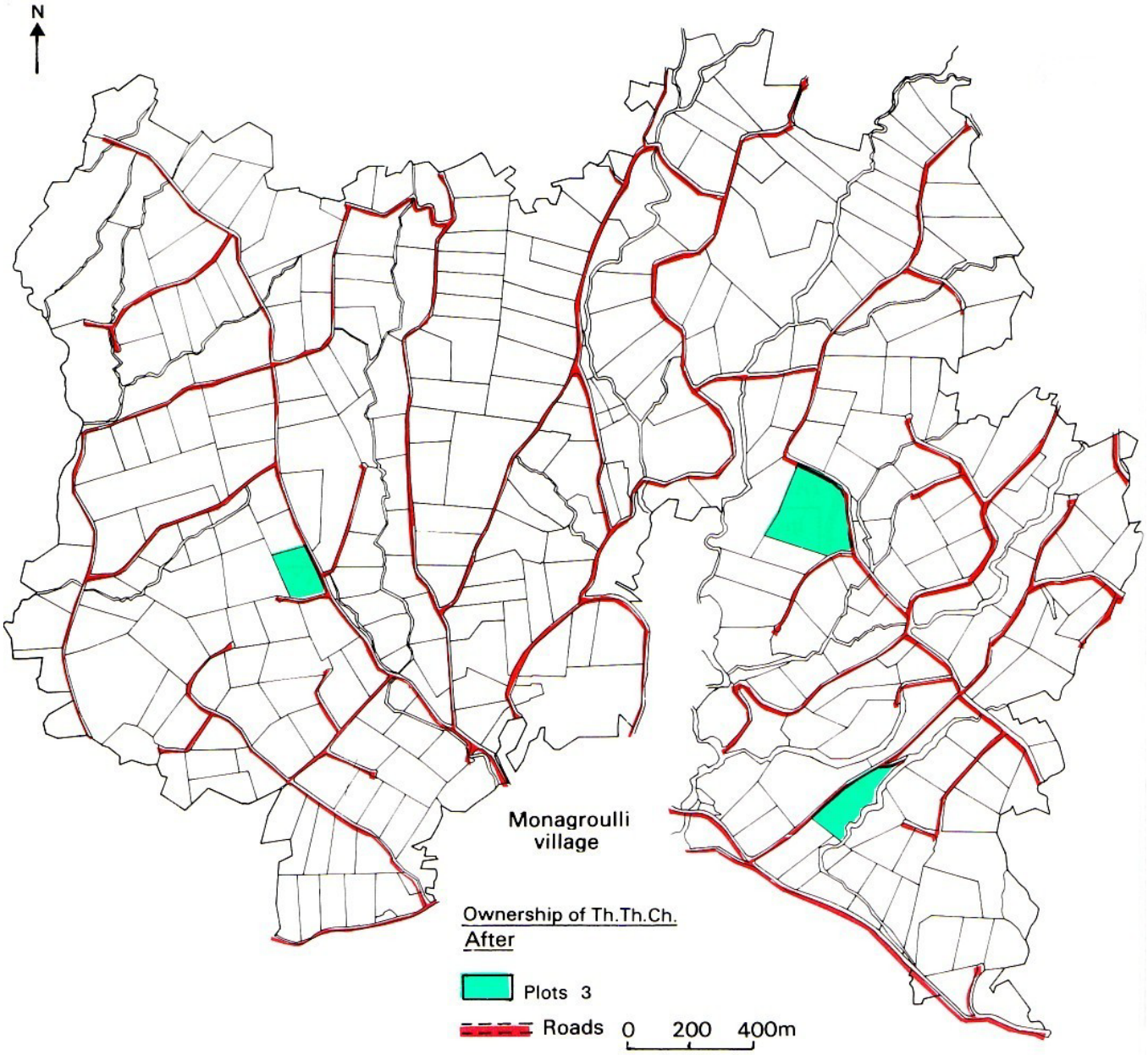
Contents

Land fragmentation



Land consolidation



Land consolidation =

Land reallocation + Infrastructure

- The problem: "How to optimally rearrange the existing land tenure structure in a certain rural area so as to fulfill the aims of a particular land consolidation project?"
- It is the most important and complex process of land consolidation

Land redistribution + Land partitioning

Land redistribution

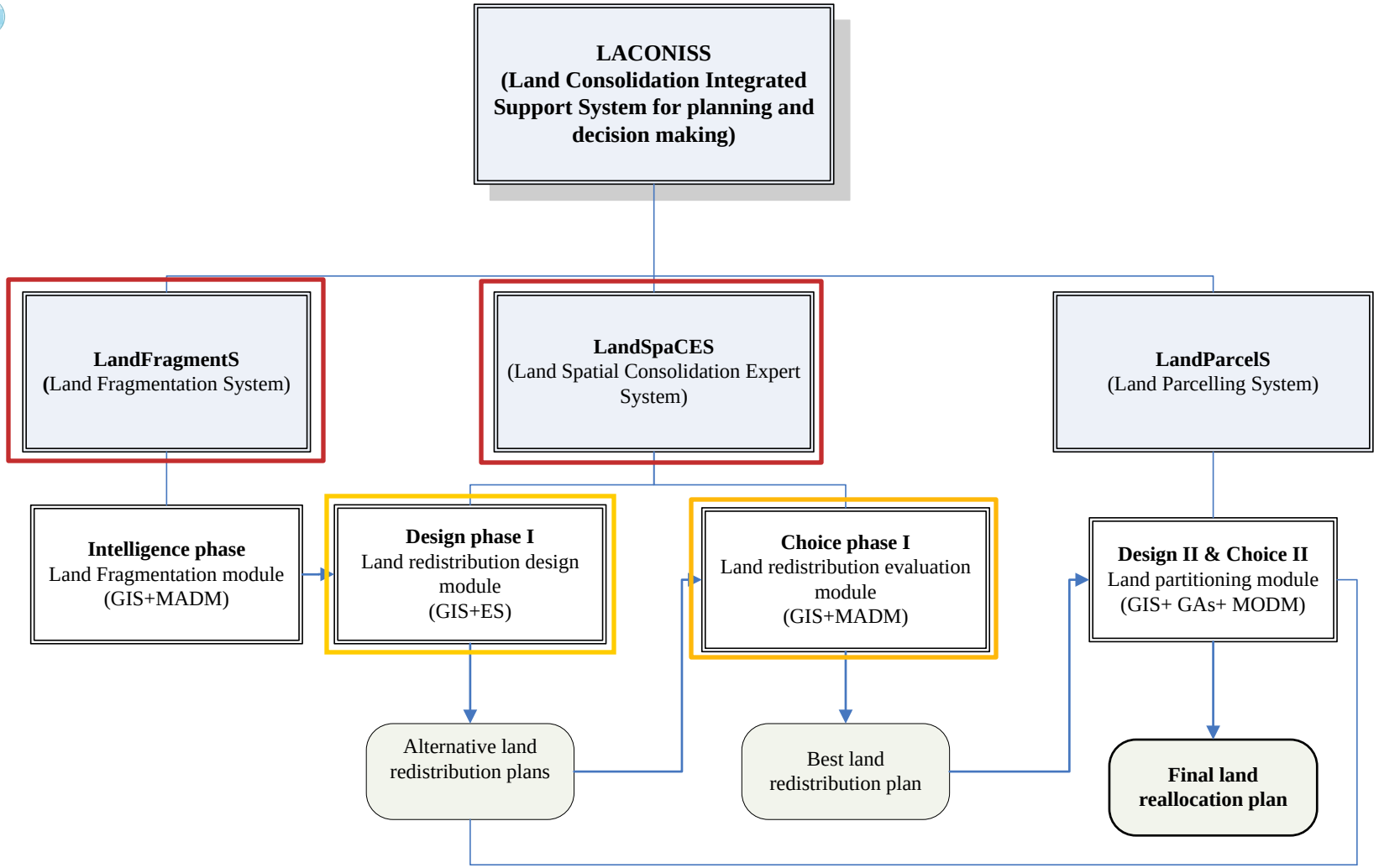
- Design problem : decision making
  - Which landowners will take property in the new plan and which not?
  - What is the total area and value of the property which will receive each landowner in the new plan?
  - How many parcels will receive each landowner in the new plan?
  - What is the area and value of each new parcel?
  - What is the approximate location of the new parcel(s) will take each landowner?
- Evaluation problem
  - Once we have a set of alternative solutions which one is the best?

LACONISS

LAnd CONsolidation
Integrated Support System for planning and decision making

2. LACONISS

The operational framework of LACONISS

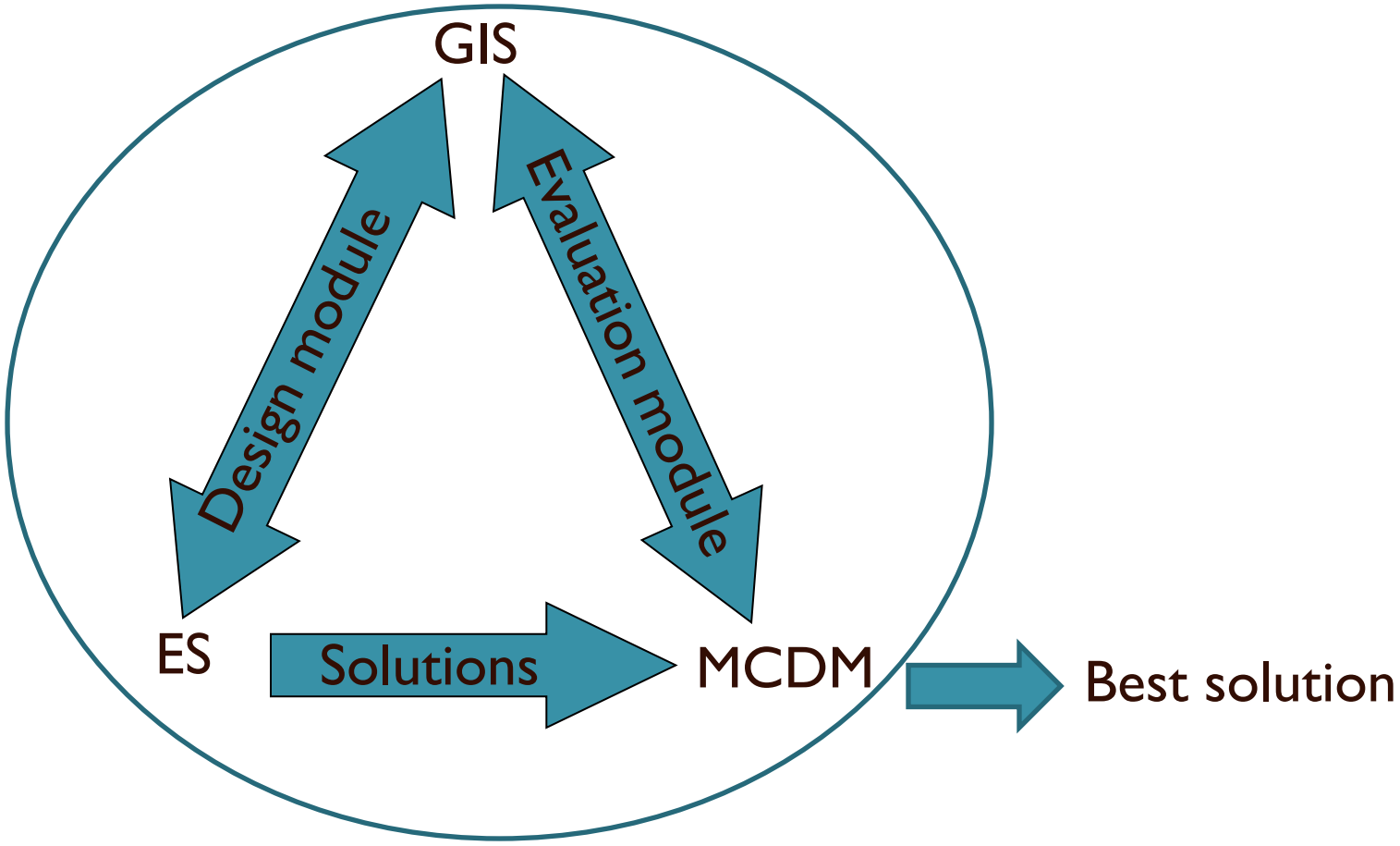


3. LandSpaCES

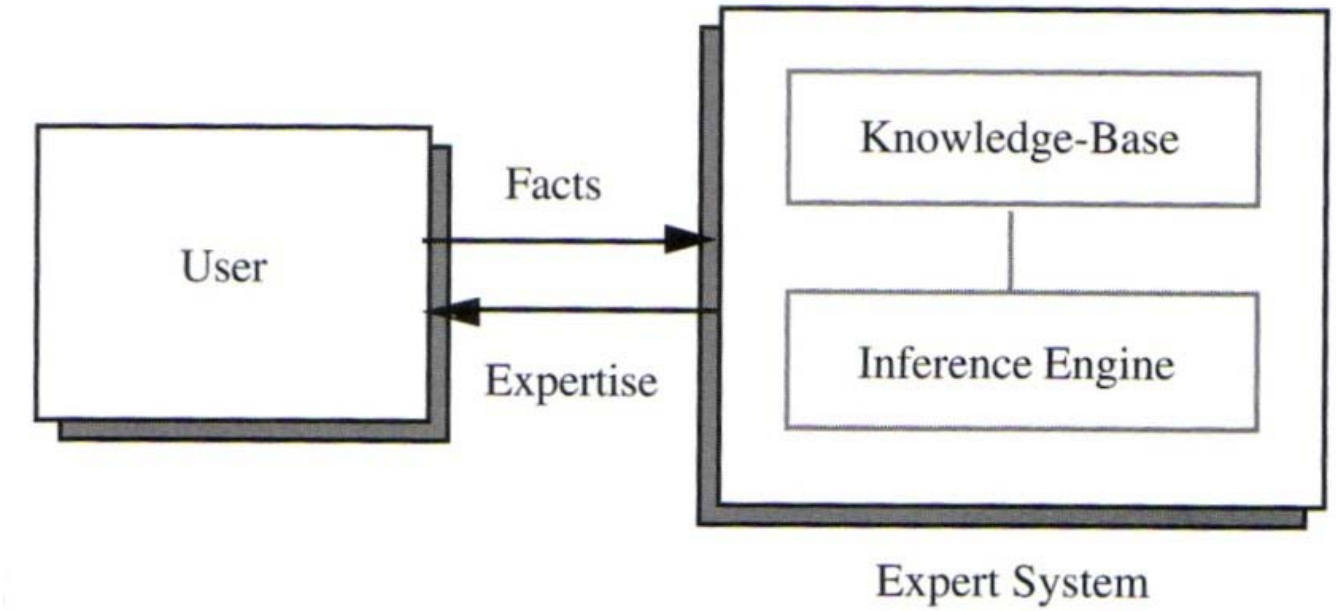
The scope of the system

- automate the process of land redistribution
- be used as a decision support tool
- structure the process in a systematic and transparent way
- considerably diminish the time needed to carry out the process
- be capable of evaluating a set of alternative land redistributions

LandSpaCES integration tools



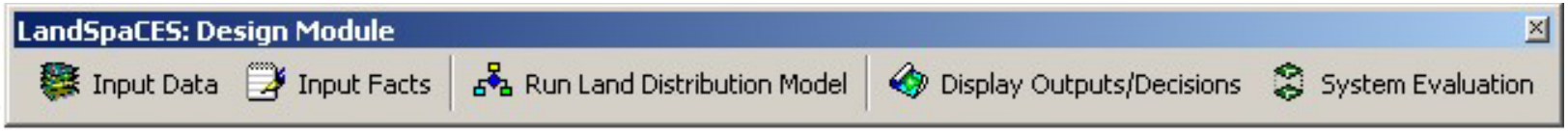
Expert systems (ES)

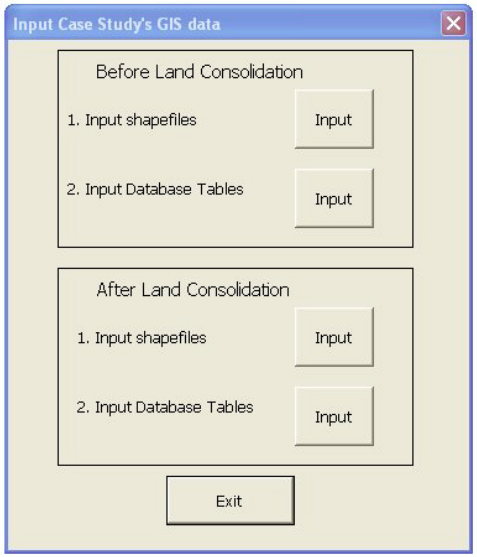


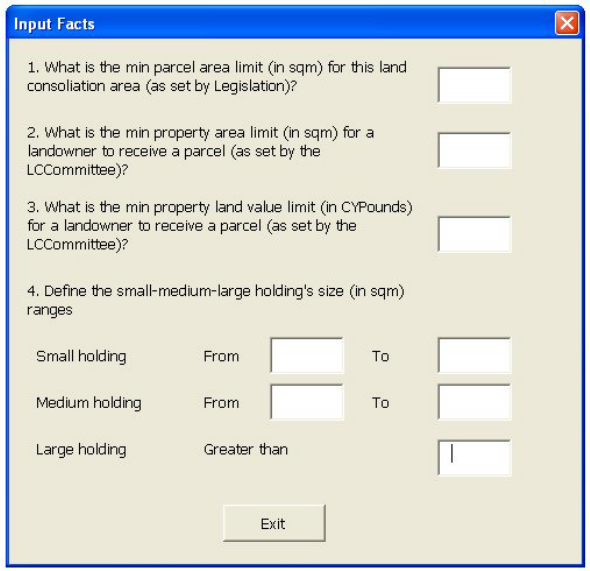
"IF this condition (or premise or antecedent) occurs THEN some action (or results or conclusion, or consequence) will or should occur".

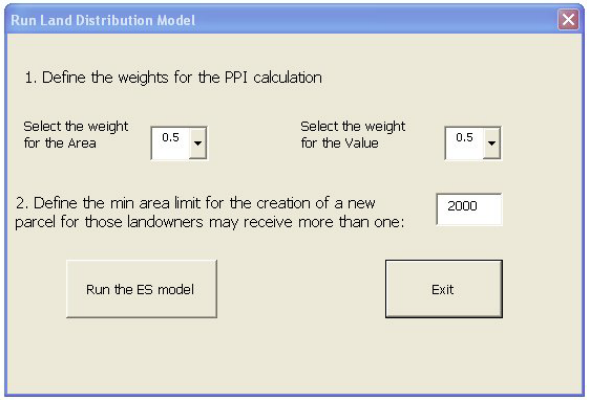
Interface

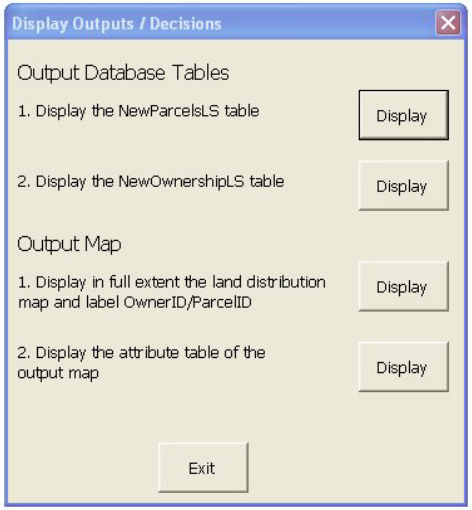
4. Design module

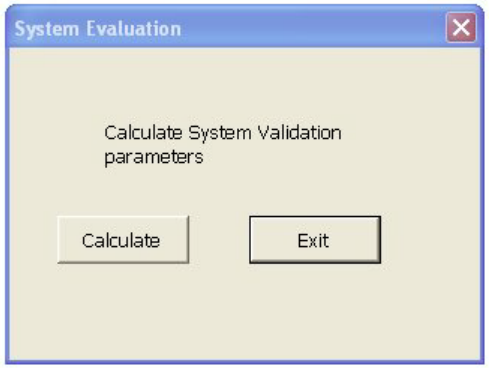




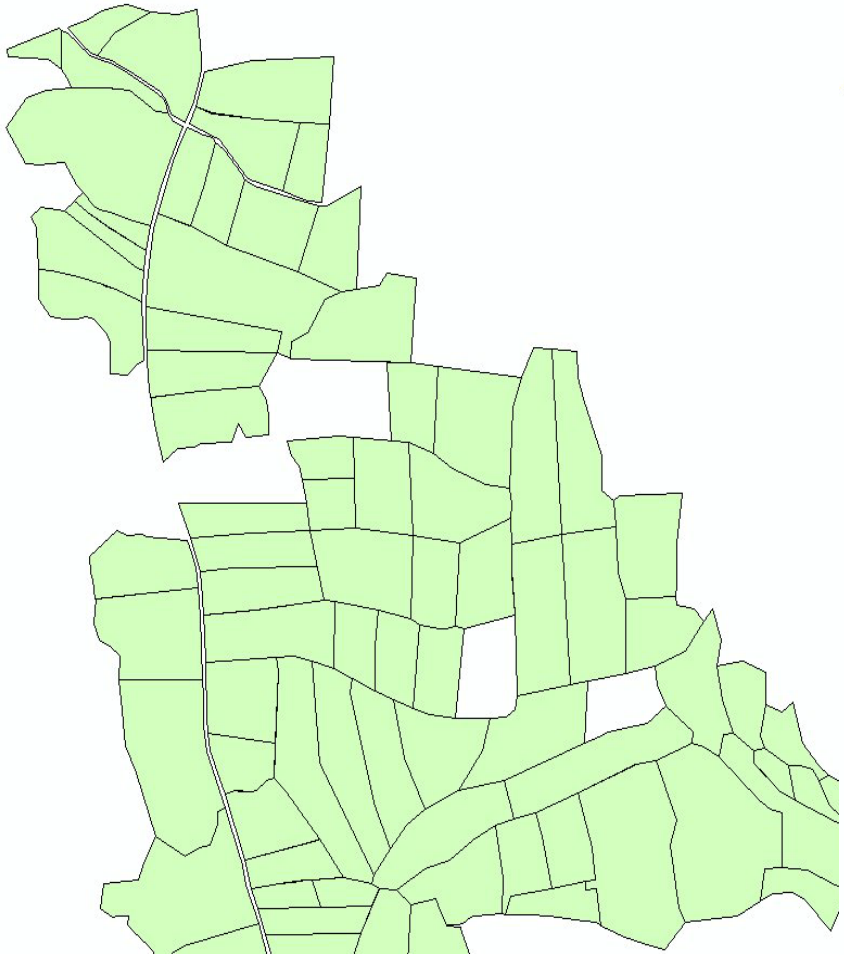




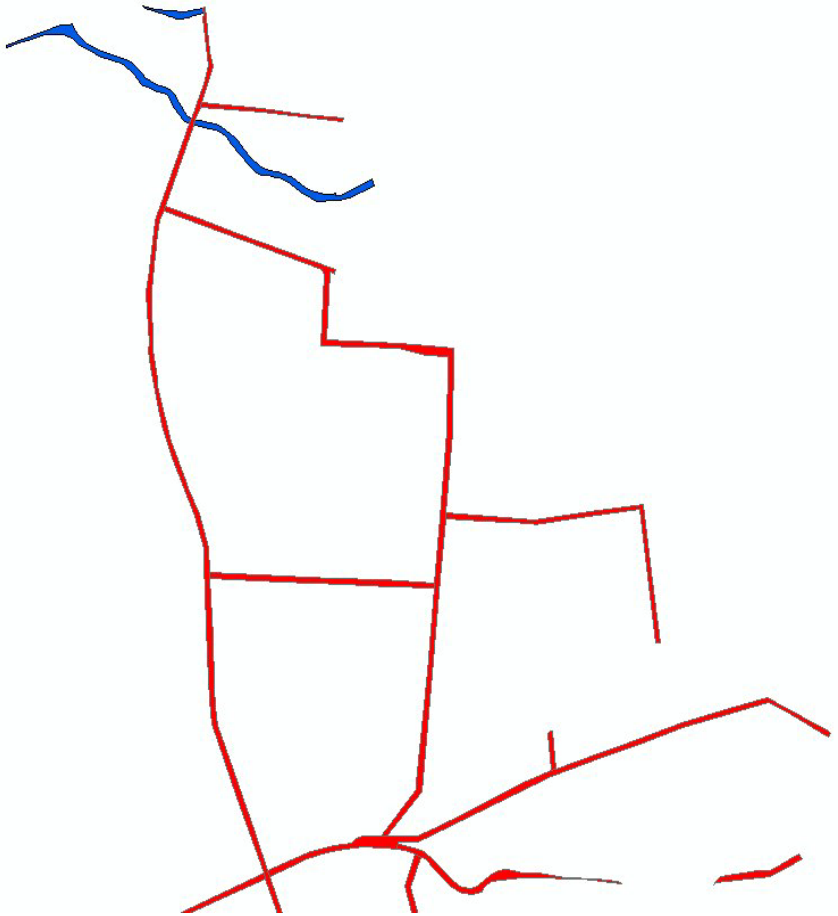




Input data: GIS layers

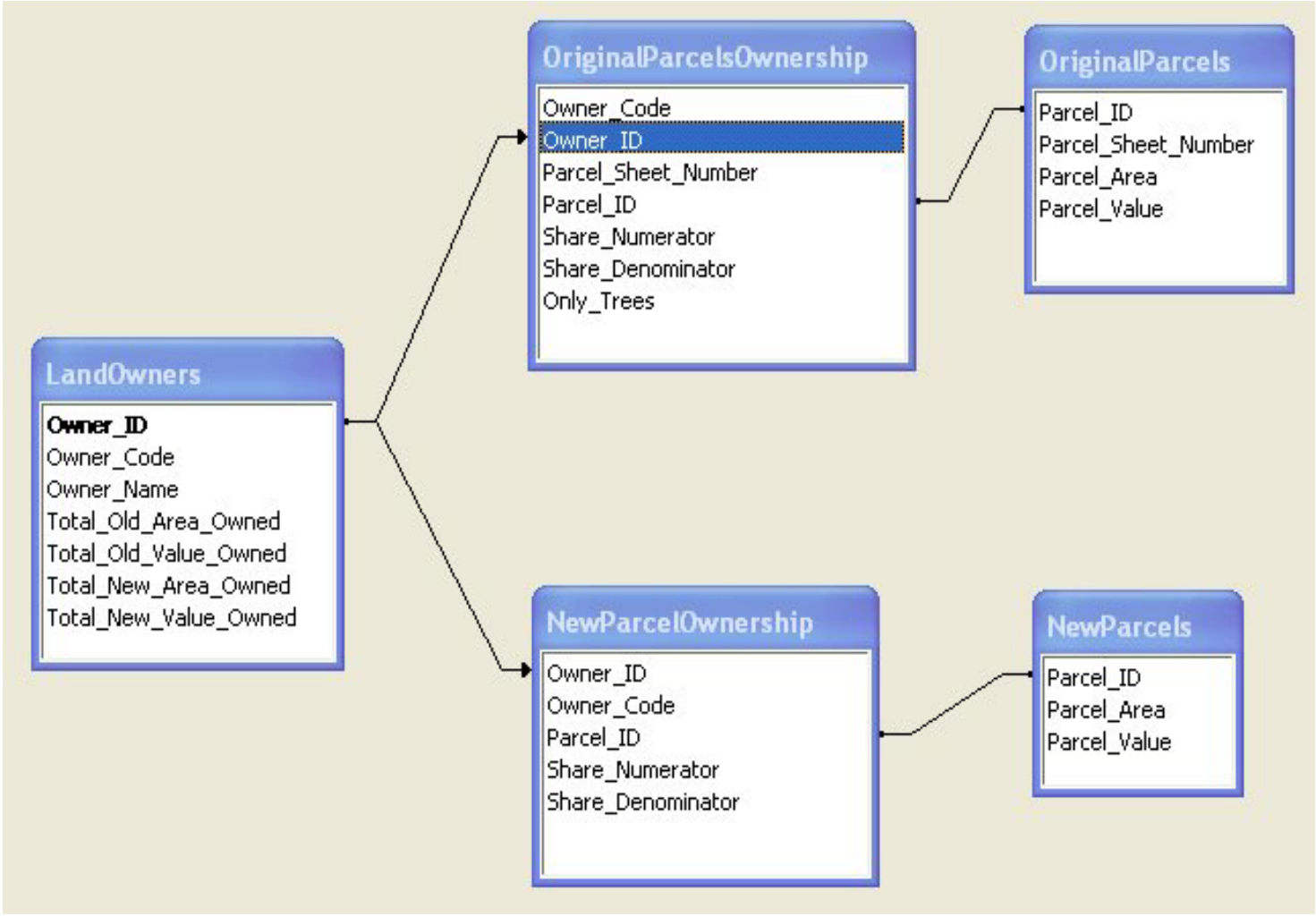


Cadastral plan



Roads and streams

Inputs data: cadastral databases



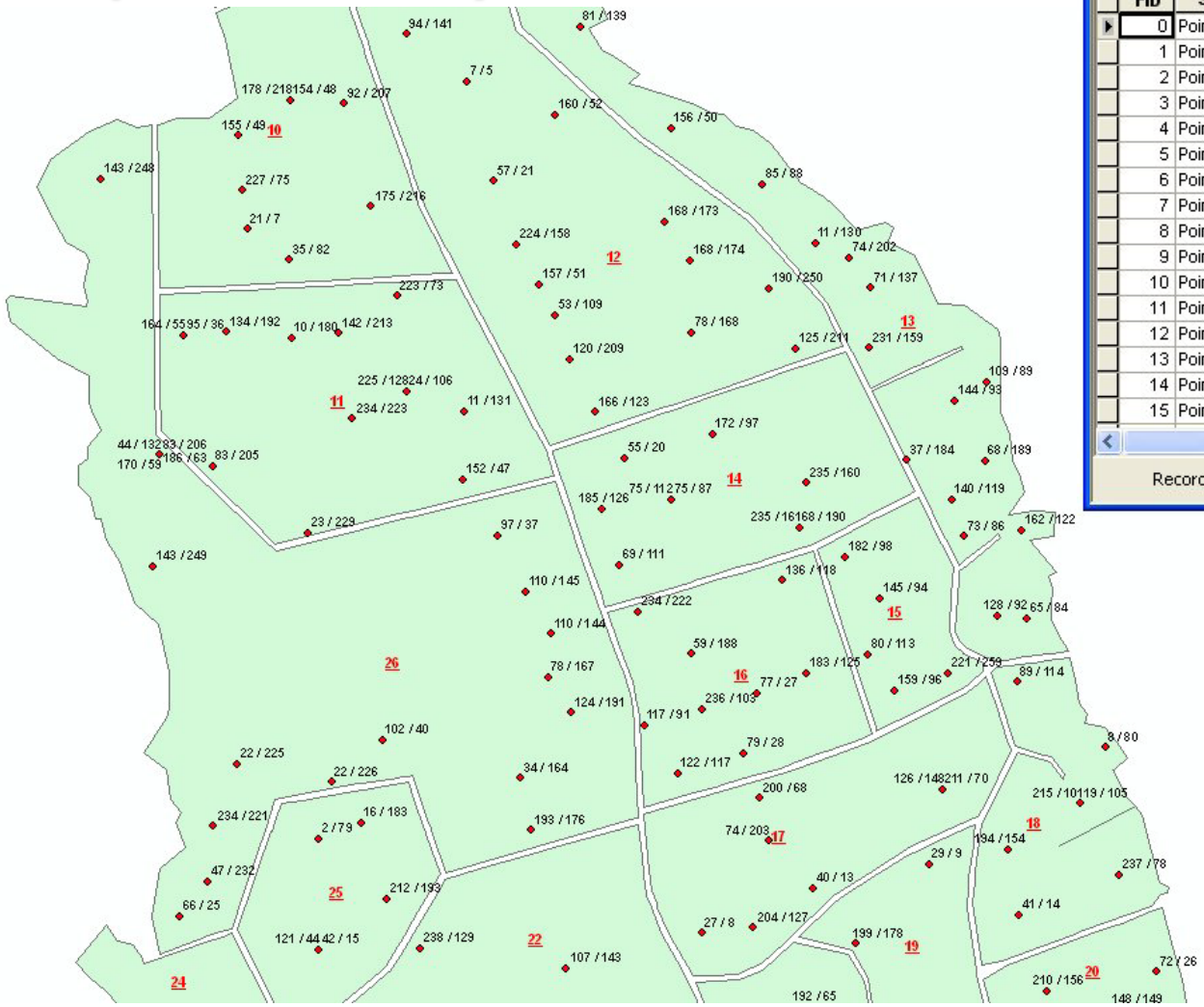
Facts: decision variables

F1	The minimum parcel area limit (in m^2) for this land consolidation area as set by legislation
F2	The minimum holding's size limit (in m^2) for a landowner to receive a parcel in the new plan as set by the Committee
F3	The minimum holding's land value limit (in CyP) for a landowner to receive a parcel in the new plan as set by the Committee
F4	The lower limit (in m^2) of a "small" holding size
F5	The upper limit (in m^2) of a "small" holding size
F6	The lower limit (in m^2) of a "medium" holding size
F7	The upper limit (in m^2) of a "medium" holding size
F8	The lower limit (in m^2) of a "large" holding size
F9	The weight for parcel area for the calculation of the PPI (Parcel Priority Index)
F10	The weight for parcel land value for the calculation of the PPI (Parcel Priority Index)
F11	The minimum residual area limit (in m^2) for the creation of a new parcel for those landowners may receive more than one
	Note: the number in brackets represents the area in donums (1 donum=1338 m^2)

- Parcel priority index (PPI) defines:
  - the priority of a landowner-parcel pair in terms of allocating a parcel in a certain location or not
  - the location preferences for the landowner's new parcels

Outputs: GIS layers

4. Design module



Attributes of ParcelsCentroids

FID	Shape	Parcel_ID	Owner_ID
0	Point	1	1
1	Point	2	3
2	Point	3	4
3	Point	4	5
4	Point	5	7
5	Point	6	12
6	Point	7	21
7	Point	8	27
8	Point	9	29
9	Point	10	31
10	Point	11	36
11	Point	12	38
12	Point	13	40
13	Point	14	41
14	Point	15	42
15	Point	16	45

Record: 1 Show:

Outputs: database tables

4. Design module

Attributes of NewParcelLS

OID	Parcel_ID	Area	Value	X_Centroid	Y_Centroid	Block	PPI
0	1	3267.23	535.49	144928.16	352915.18	8	0.324893
1	2	6535.44	923.26	145424.05	351810.65	19	0.512819
2	3	8822.7	1377.6	144995.97	353021.67	8	0.546201
3	4	2940.9	415.47	145537.59	352893.32	7	0.270247
4	5	8822.7	1446.12	145009.81	352743.21	12	0.550143
5	6	4411.35	754.4	145201.49	353051.63	7	0.55375
6	7	7841.75	1107.91	144798.5	352601.23	10	0.527578
7	8	5554.49	1171.08	145235.75	351924.33	17	0.523973
8	9	3267.23	510.22	145453.67	351990.21	19	0.316531
9	10	3021.99	809.07	145237.53	352875.09	7	0.390352
10	11	9476.34	1129.78	144998.63	353476.69	4	0.53401
11	12	3920.87	102.04	145613.08	352933.42	7	0.324038
12	13	5228.16	816.36	145343.09	351967.56	17	0.491692
13	14	8822.7	1471.87	145540.78	351941.7	18	0.551625
14	15	5881.8	481.07	144866.67	351908.01	25	0.531603
15	16	9476.34	1479.65	145291.3	353023.41	7	0.554141

Record: 1 Show: All Selected Records (0 out of 259

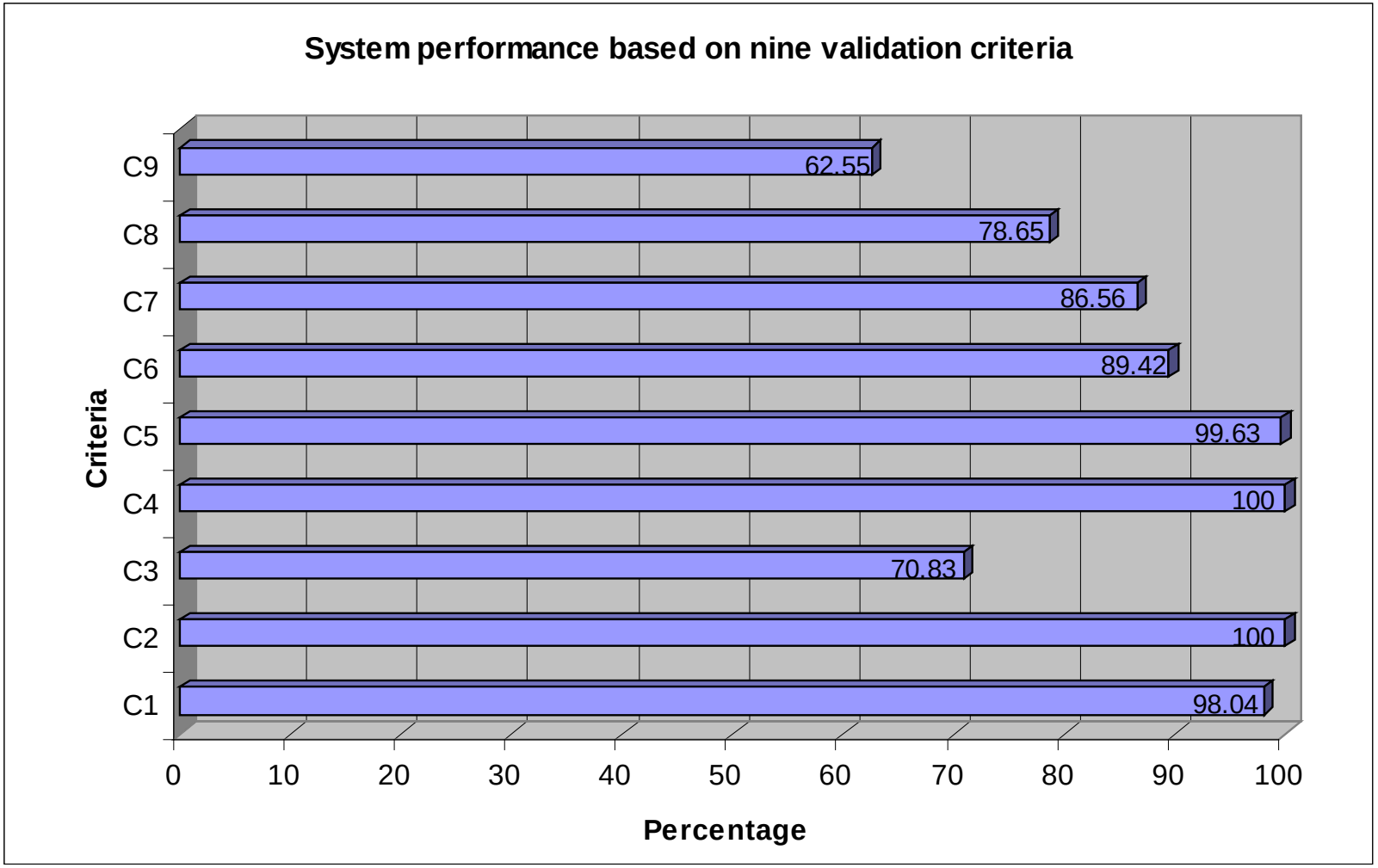
Attributes of NewOwnershipLS

OID	Parcel_ID	Owner_ID	Share_N	Share_D
0	1	1	1	1
1	2	3	1	1
2	3	4	1	1
3	4	5	1	1
4	5	7	1	1
5	6	12	1	1
6	7	21	1	1
7	8	27	1	1
8	9	29	1	1
9	10	31	1	1
10	11	36	1	1
11	12	38	1	1
12	13	40	1	1
13	14	41	1	1
14	15	42	1	1
15	16	45	1	1

Record: 1 Show: All

System Vs Human experts

4. Design module

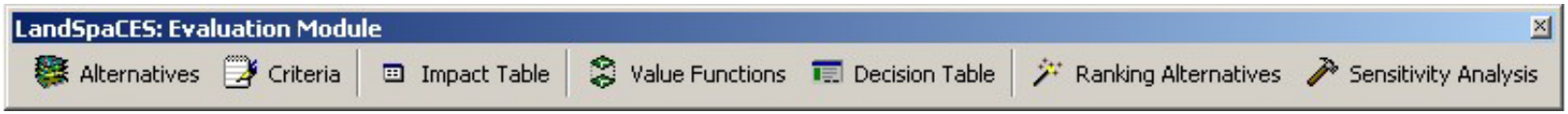


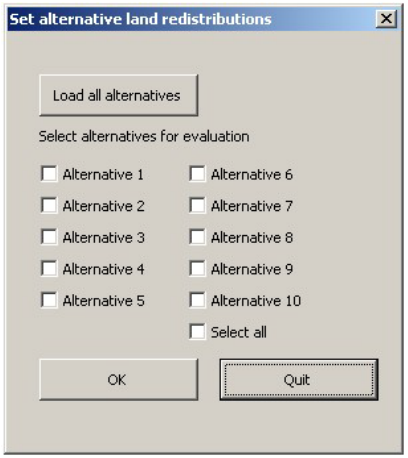
System Vs Human Experts

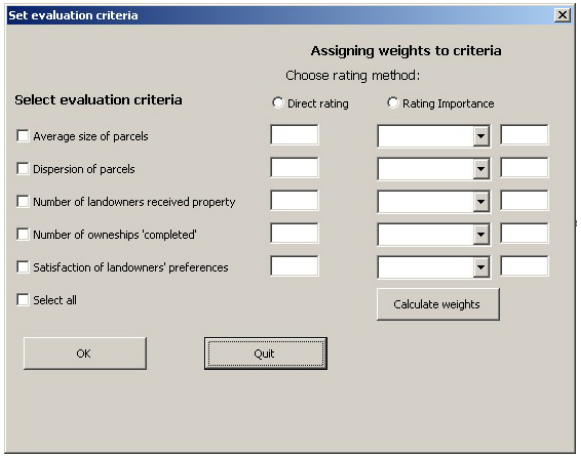
- A human expert needs about 30 working days to prepare the case study's land redistribution problem
  - Study area: 200 hectares
  - Number of parcels/shares: 480
  - Number of landowners: 253
- LandSpaCES needs only 6 minutes

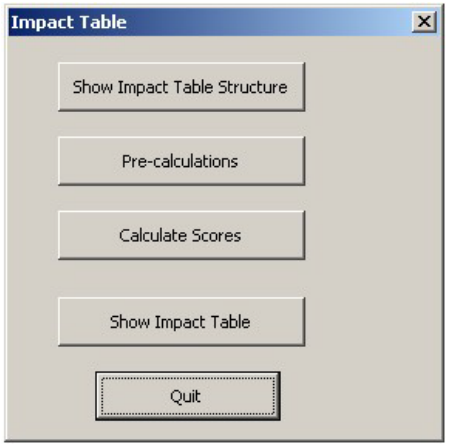
Evaluation module interface

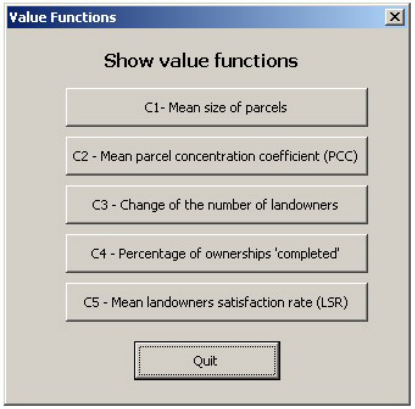
5. Evaluation module

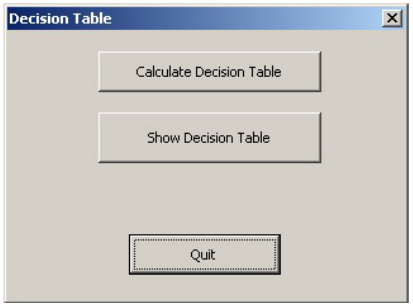


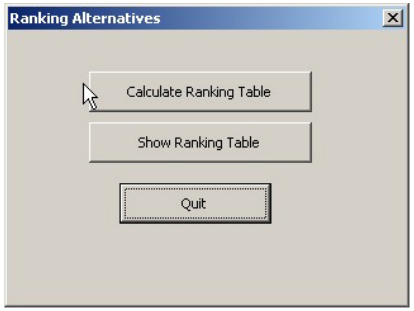


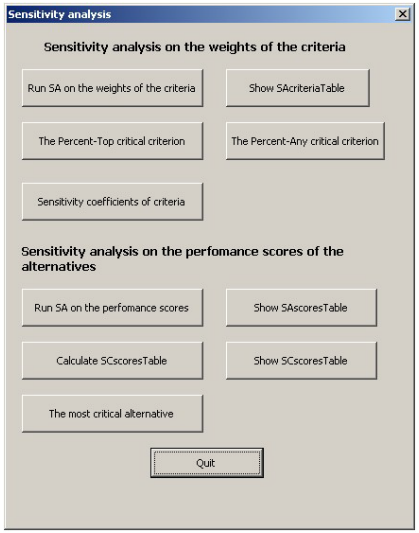




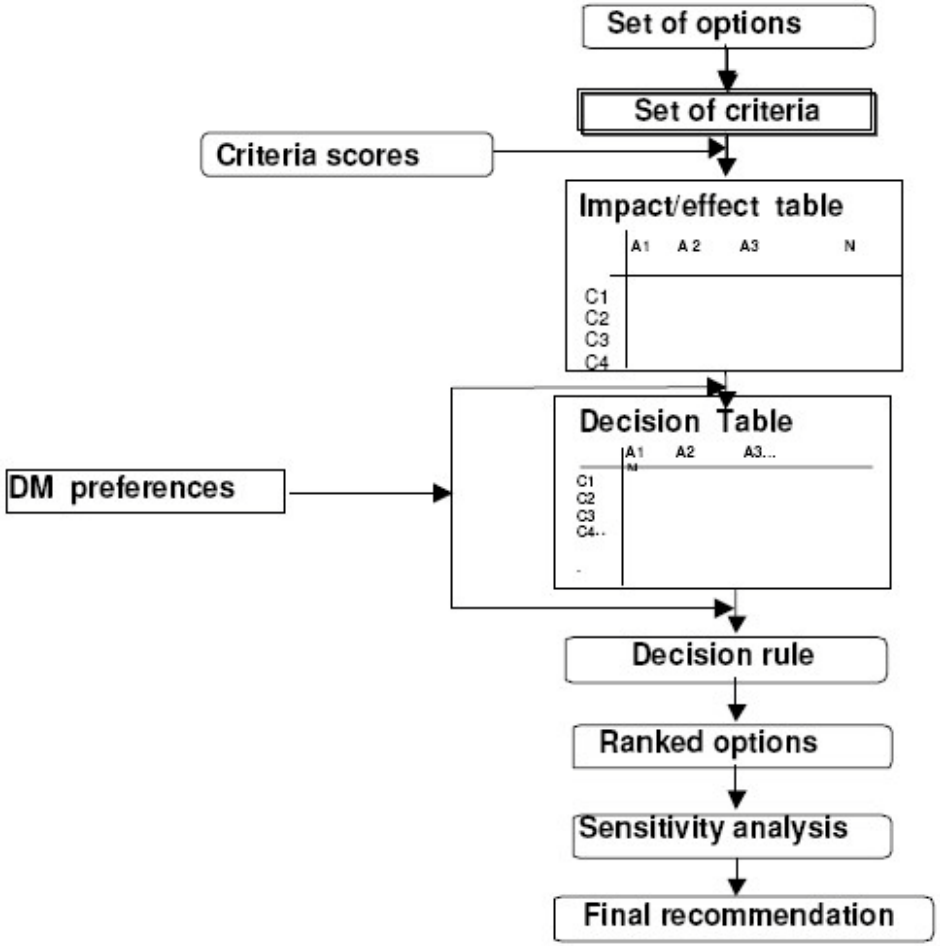








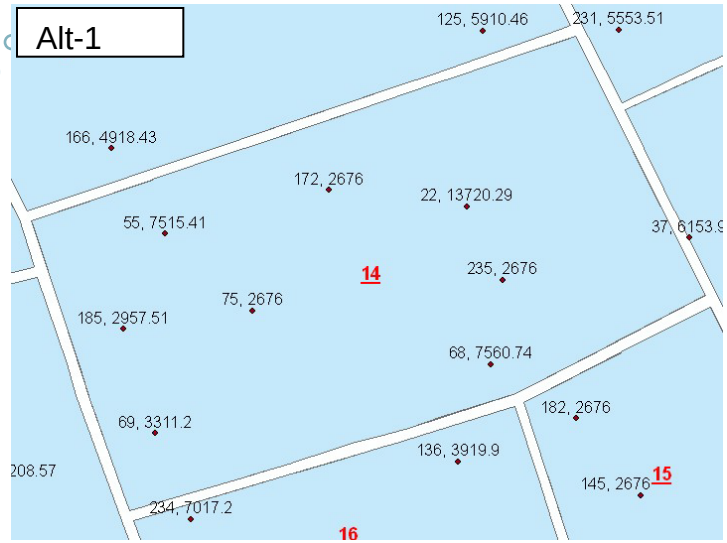
Multi-attribute decision methods (MADM)

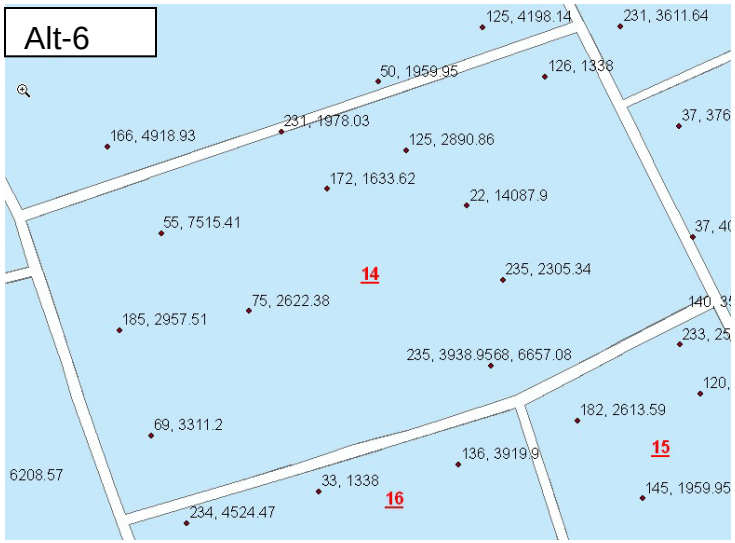


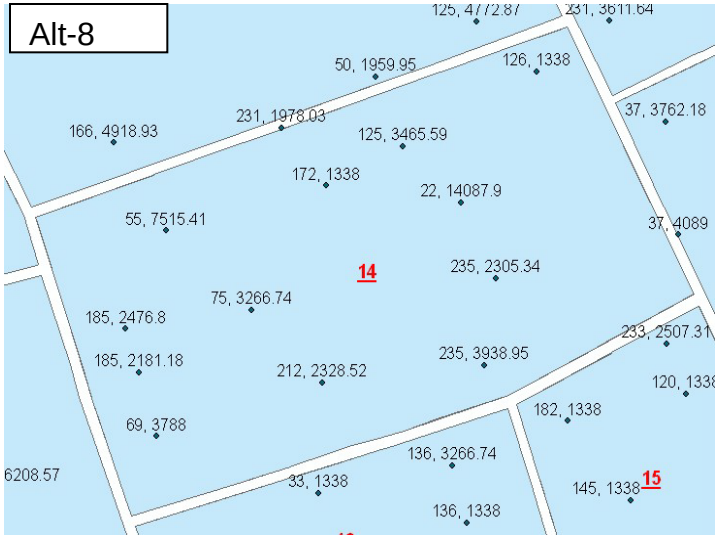
(Sharifi et al., 2004)

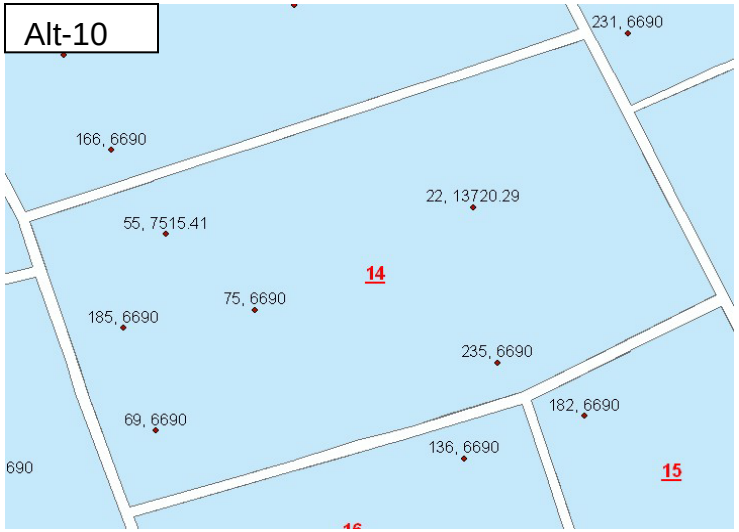
Set of alternative options

4. Design module









Set of evaluation criteria

- size of new parcels (C1)
- parcel concentration coefficient-PCC (C2) New!
- number of landowners (C3)
- landowner satisfaction rate-LSR (C4) New!
- ownerships 'completed' (C5)

5. Evaluation module

PCC calculation

$$DoP = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_{hmc})^2 + \sum_{i=1}^{n}(y_i - y_{hmc})^2}{n}}$$

If DoPb = DoPa then PCC = 0

If DoPb > DoPa

$$PCC = \frac{\left(\frac{DoP_b - DoP_a}{DoP_b}\right)}{n'}$$

If DoPb< DoPa

$$PCC = -\frac{\left(\frac{DoP_a - DoP_b}{DoP_a}\right)}{n}$$

LSR calculation

$$m_i = n - RO_i + 1$$

$$Maxm_i = n - n' + 1$$

$$P = \frac{100}{n - n' + 1}$$

$$PSR_i = \frac{100(n - RO_i + 1)}{n - n' + 1}$$

$$\bar{LSR}_j = \sum_{i=1}^{n'} \frac{PSR_i}{n'}$$

$$LSR = \sum_{j=1}^{l} \frac{LSR_j}{l}$$

Impact table

5. Evaluation module

Attributes of ImpactTable

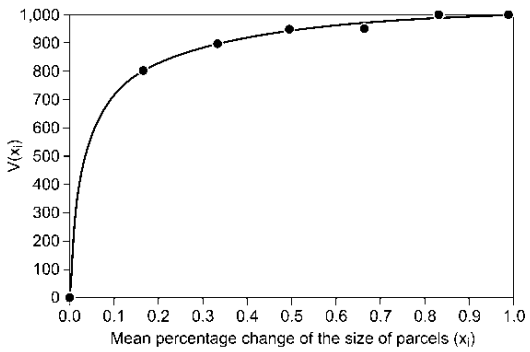
OID	Criteria	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7	Alt-8	Alt-9	Alt-10
0	Criterion-1	7248.17	7317.45	7407.05	7292.83	7170.23	6303.89	6255.04	5982.53	7242.76	9880.7686
1	Criterion-2	0.33	0.33	0.33	0.33	0.28	0.22	0.23	0.14	0.33	0.42
2	Criterion-3	210	206	201	210	210	210	213	210	210	213
3	Criterion-4	58.1081	63.5135	70.2702	58.1081	58.1081	82.6923	76.9230	40.3846	58.1081	92.5
4	Criterion-5	94.68	94.7399	95.0299	94.68	92.2200	95.9499	96.0899	95.2399	94.8399	91.080002

Record: 1 Show: All Selected Records (of 5) Options

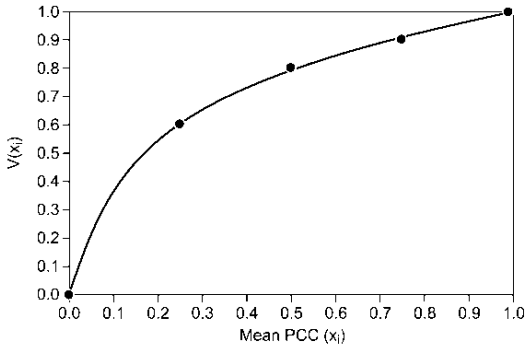
Standardisation process: Value functions

5. Evaluation module

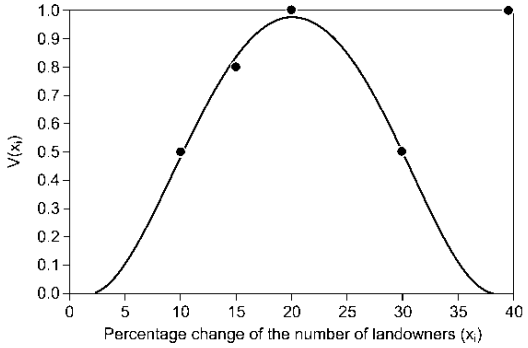
a C1: Mean percentage change of size of parcels



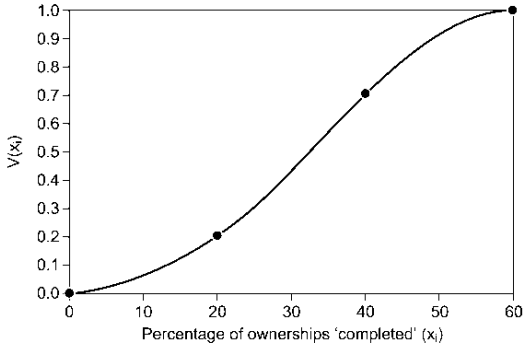
b C2: Mean PCC



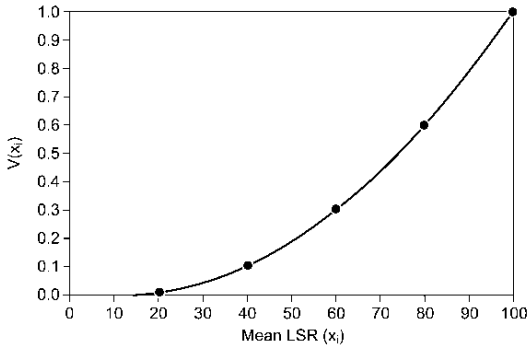
c C3: Percentage change of number of landowners



d C4: Percentage of ownerships completed

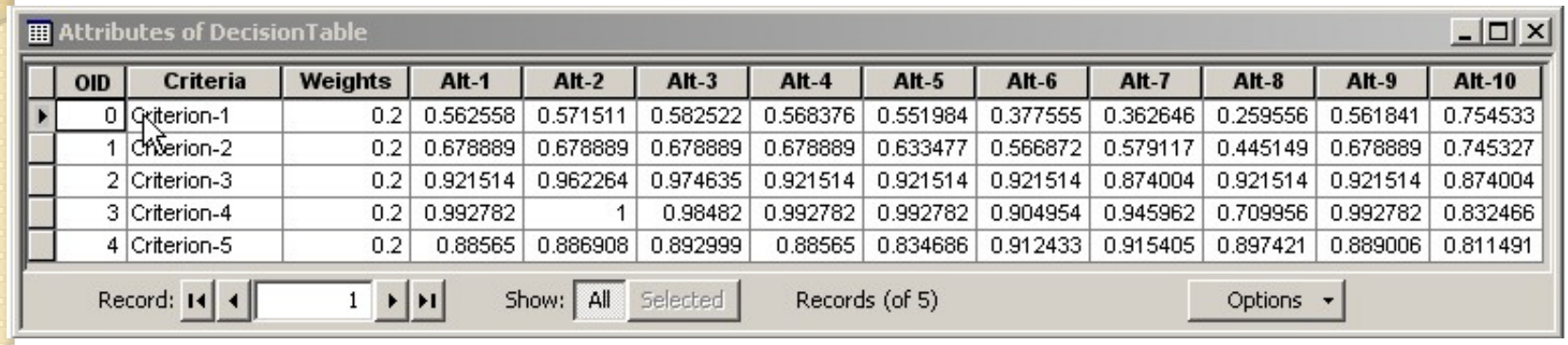


e C5: Mean LSR



Decision table

5. *Evaluation module*



Attributes of DecisionTable

OID	Criteria	Weights	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7	Alt-8	Alt-9	Alt-10
0	Criterion-1	0.2	0.562558	0.571511	0.582522	0.568376	0.551984	0.377555	0.362646	0.259556	0.561841	0.754533
1	Criterion-2	0.2	0.678889	0.678889	0.678889	0.678889	0.633477	0.566872	0.579117	0.445149	0.678889	0.745327
2	Criterion-3	0.2	0.921514	0.962264	0.974635	0.921514	0.921514	0.921514	0.874004	0.921514	0.921514	0.874004
3	Criterion-4	0.2	0.992782	1	0.98482	0.992782	0.992782	0.904954	0.945962	0.709956	0.992782	0.832466
4	Criterion-5	0.2	0.88565	0.886908	0.892999	0.88565	0.834686	0.912433	0.915405	0.897421	0.889006	0.811491

Record: 1 Show: All Selected Records (of 5) Options

Assign weights to criteria: Qualitative rating method

5. Evaluation module

Rank order	Scale of importance	Score	Classes
1	Extremely high	100	Upper
2	Very high	80	
3	High	60	
4	Intermediate	40	Middle
5	Moderate	30	Lower
6	Low	20	
7	Very low	10	

Criterion	Scale of importance	Score	Weight
C1	Extremely high	100	0.294
C2	Very high	80	0.235
C3	High	60	0.176
C4	Intermediate	40	0.118
C5	Moderate	30	0.090
C6	Low	20	0.059
C7	Very low	10	0.029
		340	1.000

$$\sum_{i=1}^{N} w_i = 1$$

Value function approach

$$V_j = \sum_{i=1}^{N} w_i v_{ij}$$

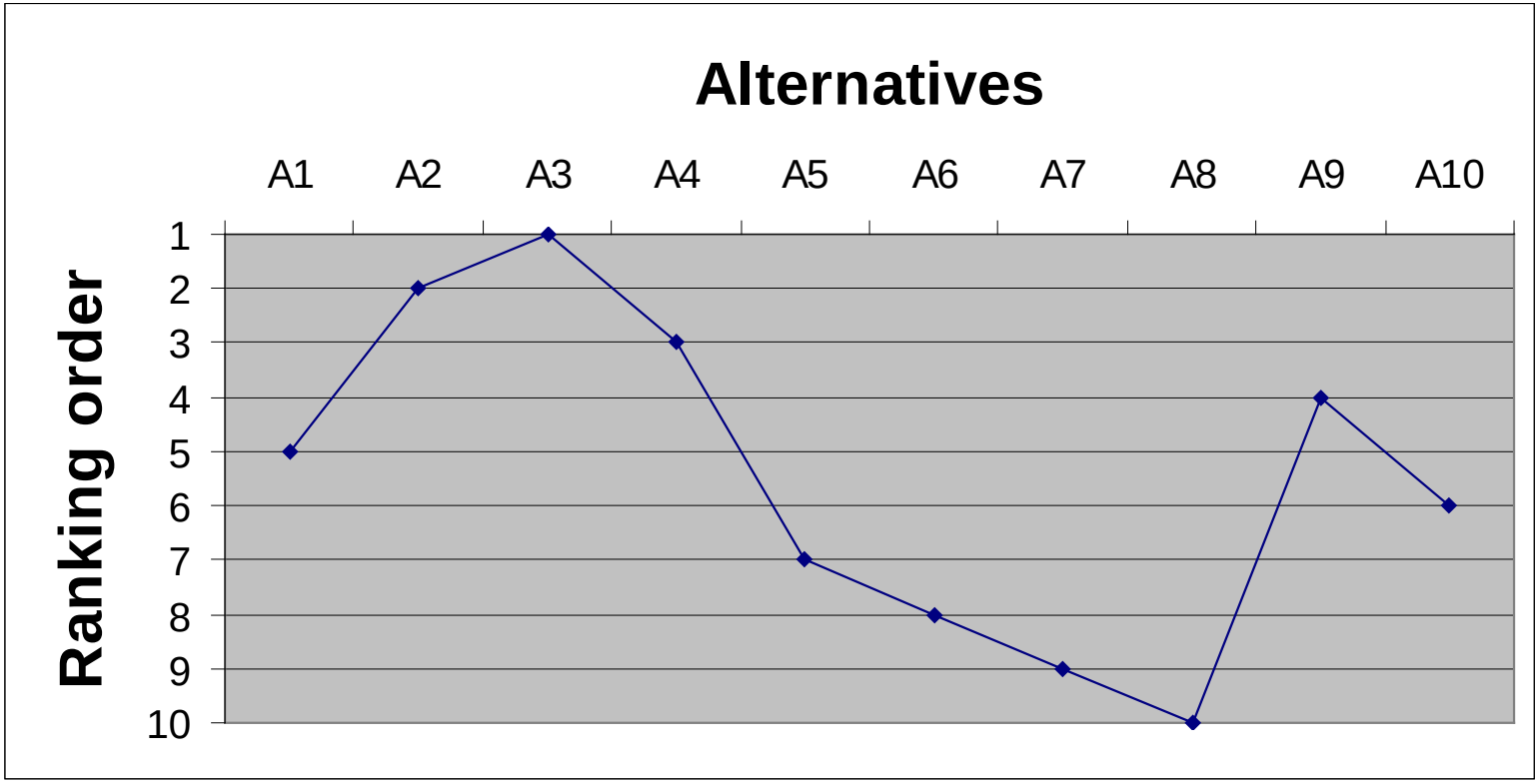
V_j is the overall value i.e. performance score of the j^{th} alternative (j =1 to M)

V_{ij} is the standardised value of the score α_{ij} in the the j^{th} alternative with respect to the i^{th} criterion (i =1 to N) measured by utilising an appropriate value function

W_i is the weight for criterion i

5. *Evaluation module*

Ranking alternative solutions



Sensitivity analysis

Triantaphyllou, 1997

- SA of weights

$$D_k^{'} = \min_{1 \le i < j \le M} \left| \delta_{k,i,j}^{'} \right| \qquad sens(C_k) = \frac{1}{D_k^{'}}$$

- SA of performance scores

$$R = \frac{(P_i - P_k)}{W_k} \times \frac{100}{a_{ij}}$$

Attributes of SAcriteriaTable

OID	Alt(i)	Alt(j)	C1	C2	C3	C4	C5
23	3	10	-89.82	-232.56	11111	81.13	1111111
24	4	5	11111	111111	11111	11111	1111111
25	4	6	11111	111111	11111	11111	-1132.44
26	4	7	11111	111111	11111	11111	-1006.44
27	4	8	11111	111111	11111	11111	-5990.06
28	4	9	35.791	111111	11111	11111	-55.7429
29	4	10	-47.27	-132.46	11111	43.91	94.94031
30	5	6	11111	111111	11111	11111	-260.983
31	5	7	11111	111111	11111	11111	-246.618
32	5	8	11111	111111	11111	11111	-963.893
33	5	9	11111	111111	11111	11111	1111111
34	5	10	18.514	33.5271	-78.93	-18.71	-129.338
35	6	7	-32.19	39.1945	-10.10	9.363	1111111
36	6	8	11111	111111	11111	11111	1111111
37	6	9	11111	111111	11111	11111	-1286.72
38	6	10	77.228	111111	-612.7	-321.3	-230.733
39	7	8	11111	111111	-1067.	11111	1111111
40	7	9	11111	111111	11111	11111	-1127.33
41	7	10	73.065	111111	11111	-201.8	-220.439
42	8	9	11111	111111	11111	11111	-8357.47
43	8	10	11111	111111	-1669.	11111	-738.621
44	9	10	-44.45	-128.94	11111	42.75	88.41496

Record: 28 Show: All Selected

Attributes of SAscoresTable

OID	Alt(i)	Alt(j)	C1	C2	C3	C4	C5
0	1	2	-10.718635	-8.881943	-6.54342	-4.858953	-5.446717
1	1	3	-12.855529	-10.652669	-7.847933	-5.827646	-6.532589
2	1	4	-1.034141	-0.856936	-0.631314	-0.468795	-0.525503
3	1	5	21.276097	17.63033	12.988449	9.644844	10.811534
4	1	6	66.362081	54.990604	40.512154	30.083145	33.722158
5	1	7	65.508927	54.283643	39.991328	29.696395	33.288625
6	1	8	1111111	1111111	95.013228	70.554055	79.088639
7	1	9	-0.618366	-0.512406	-0.377495	-0.280316	-0.314225
8	1	10	14.610101	12.106587	8.919049	6.623026	7.424181
9	2	1	10.550715	8.881943	6.266317	4.823883	5.43899
10	2	3	-2.103417	-1.770727	-1.249269	-0.961701	-1.084331
11	2	4	9.532775	8.025007	5.661739	4.358471	4.914233
12	2	5	31.493497	26.512273	18.704728	14.399113	16.235187
13	2	6	75.873156	63.872547	45.06285	34.689896	39.113309
14	2	7	75.033369	63.165586	44.56408	34.305937	38.680391
15	2	8	1111111	1111111	97.255897	74.868698	84.415432

Record: 1 Show: All Selected Records (of 90)

Attributes of SCscoresTable

OID	Alt(i)	C1	Alt-C1	C2	Alt-C2	C3	Alt-C3	C4	Alt-C4	C5	Alt-C5
0	1	0.618366	9	0.512406	9	0.377495	9	0.280316	9	0.314225	9
1	2	2.103417	3	1.770727	3	1.249269	3	0.961701	3	1.084331	3
2	3	2.06366	2	1.770727	2	1.233412	2	0.976525	2	1.076934	2
3	4	0.41152	9	0.34453	9	0.253819	9	0.188479	9	0.211278	9
4	5	6.793695	10	5.919721	10	4.0694	10	3.021818	10	3.594175	10
5	6	1.2712	7	0.846661	7	0.520826	7	0.424285	7	0.420807	7
6	7	1.323463	6	0.828758	6	0.549137	6	0.405892	6	0.419441	6
7	8	193.497422	6	112.823942	6	54.501075	6	56.59338	6	44.771422	6
8	9	0.416306	4	0.34453	4	0.253819	4	0.188479	4	0.21048	4
9	10	4.969975	5	5.031358	5	4.29061	5	3.603758	5	3.696908	5

Record: 1 Show: All Selected Records (of 10) Options

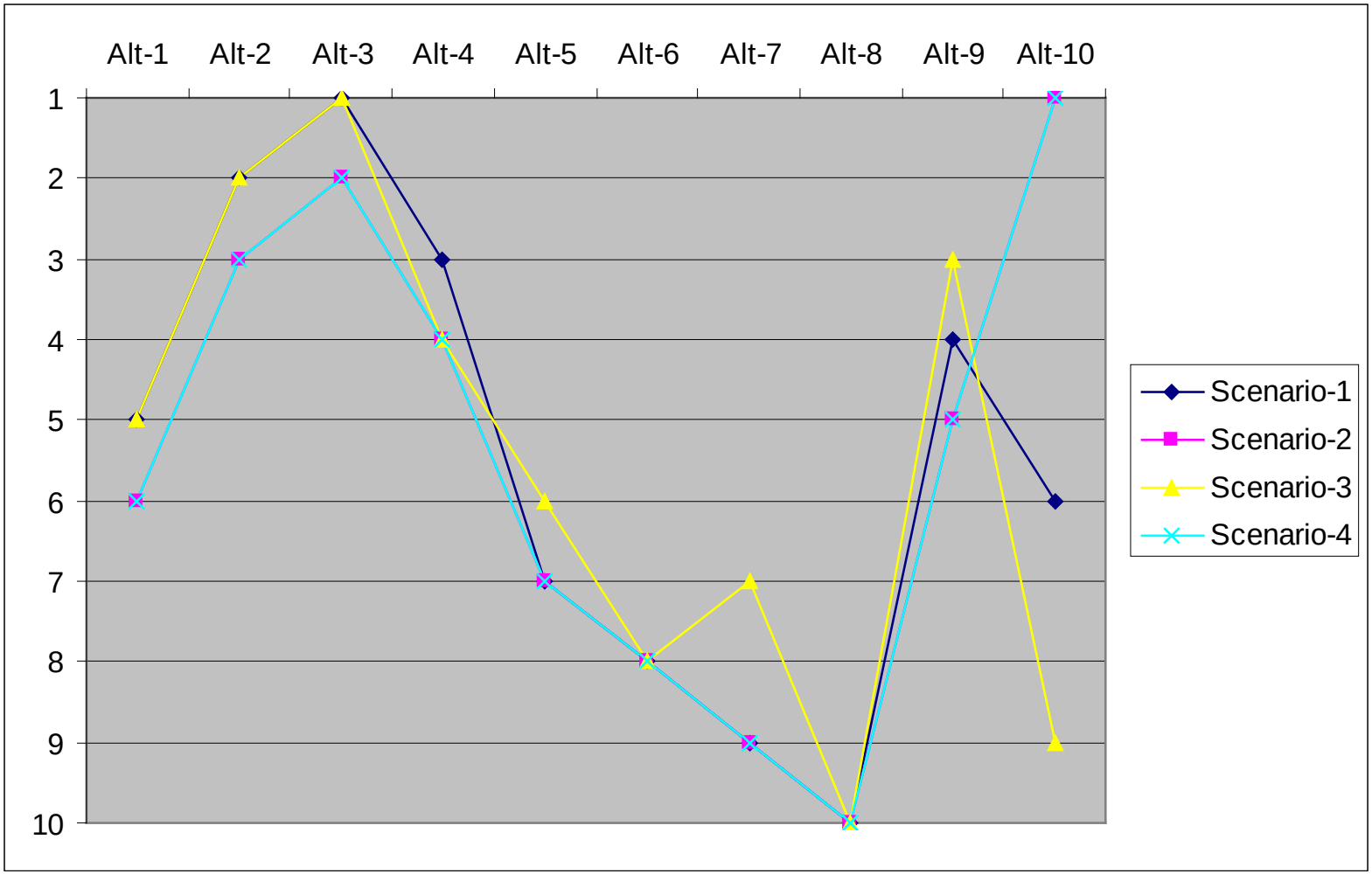
5. Evaluation module

Case study: 10 alternatives

Alternative	Description
A1	Experts solution (Irrigated project)
A2	Medium area and land value minimum limits
A3	High area and land value minimum limits
A4	Unequal PPI weights for area and land value
A5	Low small-medium-large holdings sizes
A6	High minimum area of new parcels with high area and land value minimum limits
A7	Low minimum area of new parcels with high area and land value minimum limits
A8	Low area and land value minimum limits with low small-medium-large holdings sizes
A9	Inverse unequal PPI weights for area and land value (comparing to alt-4)
A10	Arid project

5. Evaluation module

Ranking alternative solutions



Alt-1=Experts solution

Conclusions

- LandSpaCES is a powerful planning tool for land consolidation
- High system performance of the Design module
- Integration of GIS with ES is still valuable for solving complex spatial planning problems
- Evaluation module provides a comprehensive and flexible evaluation of alternative land redistribution plans
- Value functions is an excellent manner to incorporate experts knowledge in the evaluation process
- Potential applicability to other countries

Many thanks for your attention and patience!