ARID CLUSTER CYPRUS CONFERENCE

Coping with Drought and Water Deficiency:

From Research to Policy Making

Characterization of coupled socio-natural systems

BONET, A.; BELLOT, J.; SÁNCHEZ, J.R.; EISENHUTH, D; PEÑA, J.

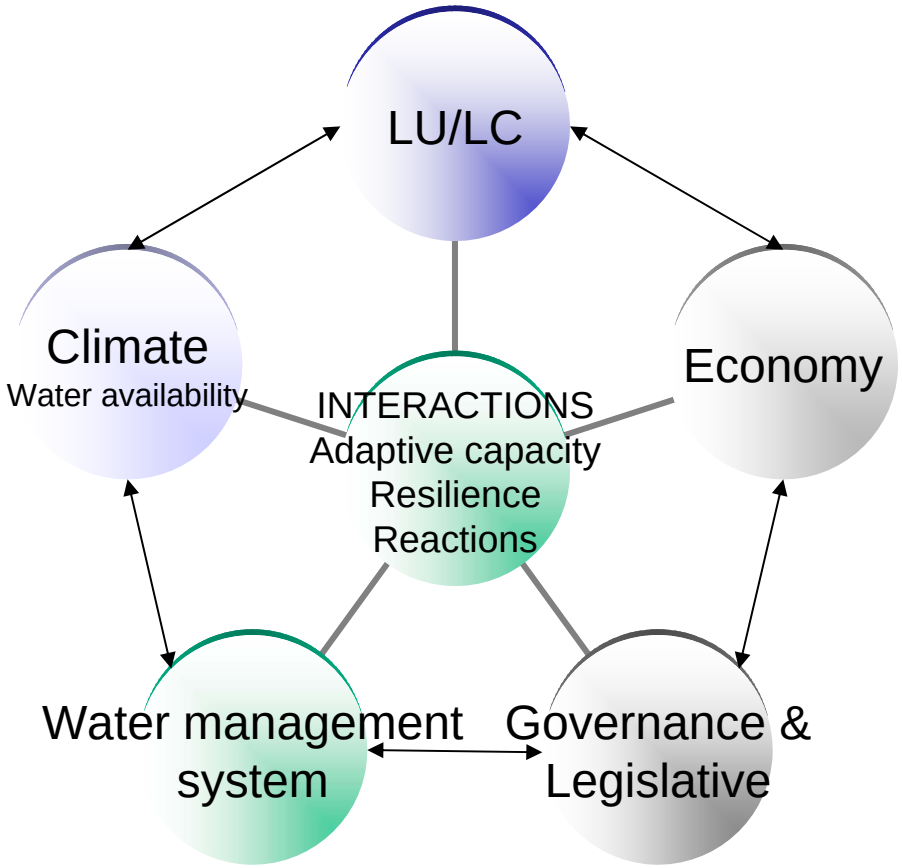
Universitat d'Alacant
Universidad de Alicante

Aims

- The identification of the co-dynamic processes between landscape, water usage, management system and governance is crucial to determine the causes of structural change in a socio-natural system of semi-arid areas.
- Our hypothesis is that if co-dynamic processes cause structural change in socio-natural systems, then structural change could offer the key through which to identify the characteristics of both the type of resilience and adaptive capacity that maintains the long-term sustainability of a socio-natural system .

Universitat d'Alacant
Universidad de Alicante

Coupling Socio-natural Systems



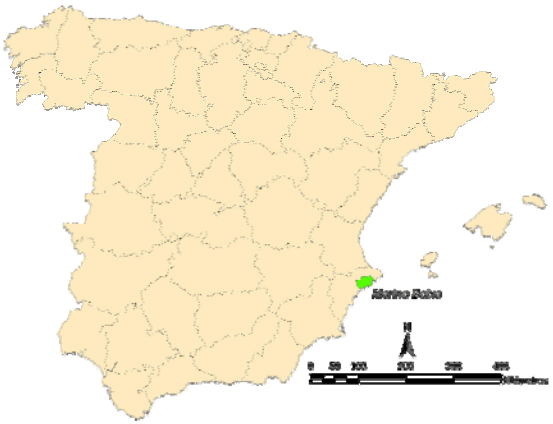
Universitat d'Alacant
Universidad de Alicante

Outlines

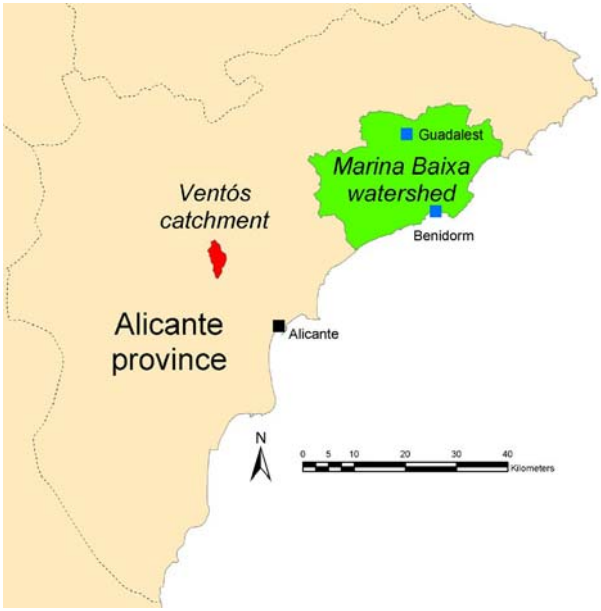
- MB Study area
- Climate change
- Land use/land cover change
- Water balances
- Water management system changes

Universitat d'Alacant
Universidad de Alicante

Case study: Marina Baixa (Spain)



Marina Baixa County
MB



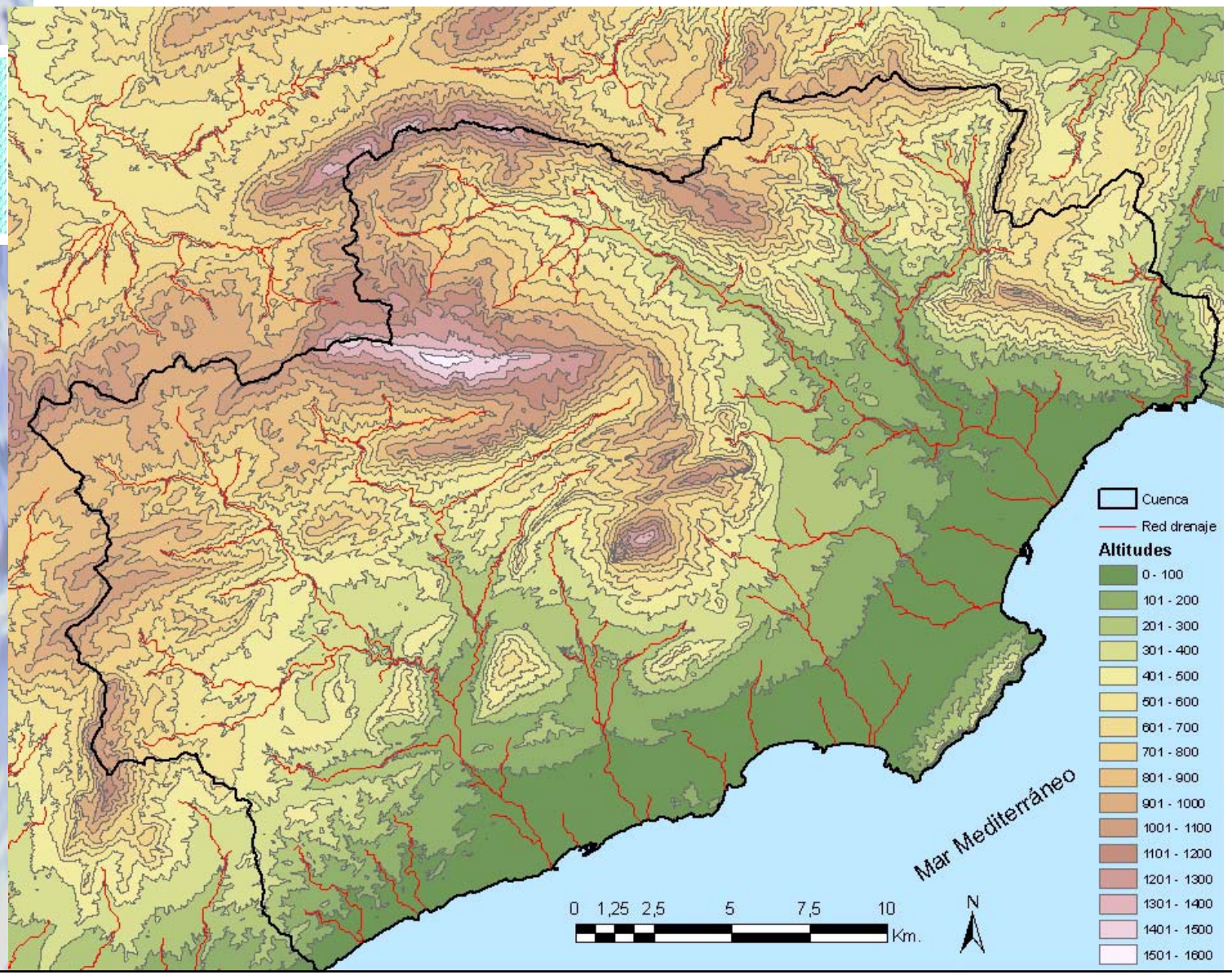
Universitat d'Alacant
Universidad de Alicante

Marina Baixa

Catchment area: 641 Km^2

County area (18 municipalities): 578,5 Km^2

Digitized study area : 680,7 Km^2



Universitat d'Alacant
Universidad de Alicante

Climate change (1950-2000)

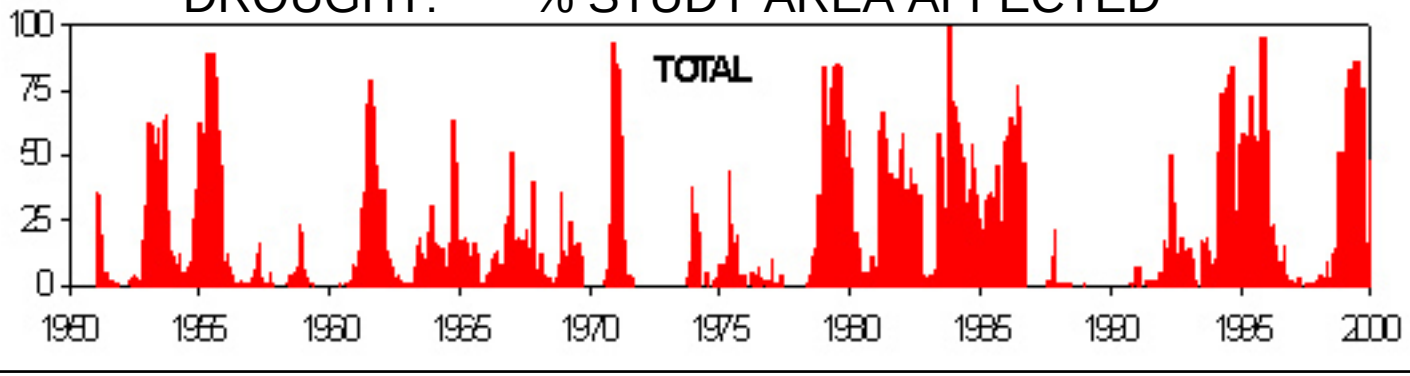
•ANNUAL RAINFALL has significantly DECREASE in the Region of Valencia over the 1950-2000 period. Rainfall decrease in Marina Baixa area has occur at a rate: -20 mm per decade

•Trend analysis shows an INCREASE of DROUGHTS FREQUENCY

•RAINFALL VARIABILITY has significantly INCREASE in the study area over the 1950-2000 period. Rainfall variability increase has occurred at a rate: +5% per year.

•Trend analysis shows an INCREASE of DROUGHTS FREQUENCY and an INCREASE in torrentiality over the 1950-1990 period.

DROUGHT: % STUDY AREA AFFECTED



Universitat d'Alacant
Universidad de Alicante

Land use/ land cover changes (1956-2000)

Changes at landscape level (County/catchment)

•Trend analysis shows an INCREASE in woodlands (inland), irrigation & urban uses (coastal municipalities), water bodies

• Trend analysis shows a DECREASE in dry crops

•Processes of change:

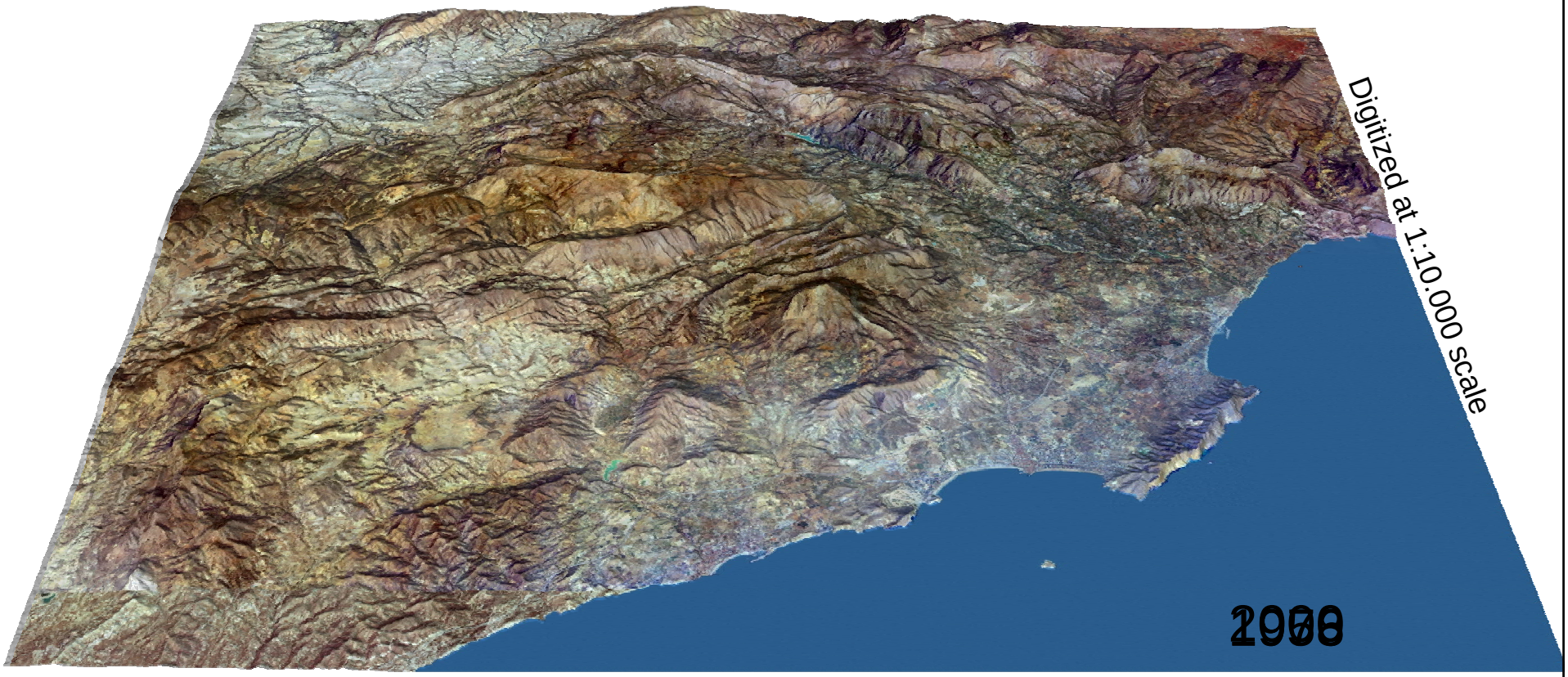
- •urbanization, irrigation, disturbances (wildfires), natural recovery, afforestation.
- •Depending on geographical position (mountain- valley, coast-inland)

•Irreversibility of some changes

•Landscape ecology patterns: fragmentation

Universitat d'Alacant
Universidad de Alicante

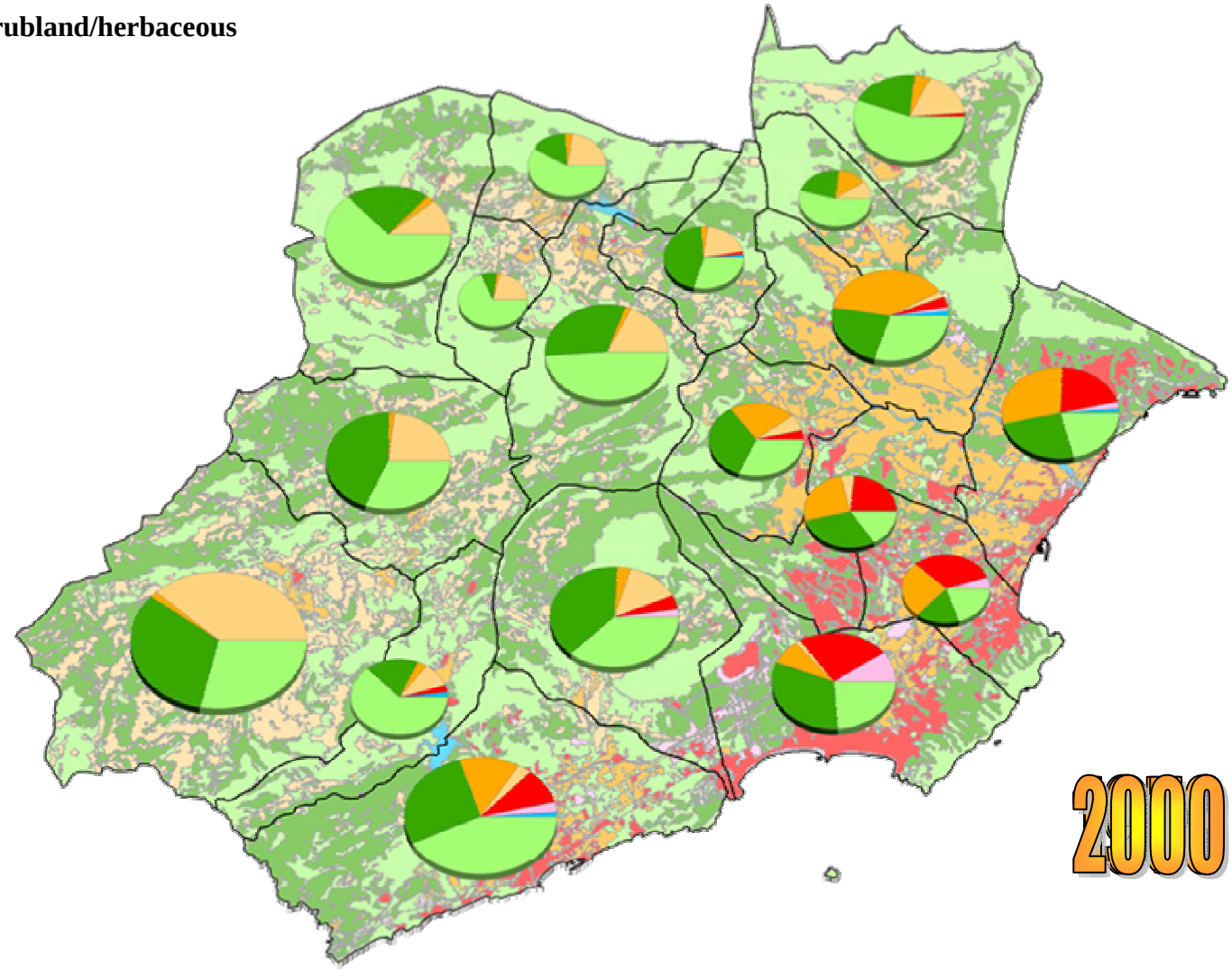
Land cover / use changes 1956-2000



- Sea
- Rivers
- Water bodies
- Dams
- Beaches
- Leisure facilities
- Industrial and commercial
- Infrastructure
- Principal roads
- Secondary roads
- Regional/local roads
- Access roads
- Railway
- Low density residential
- Medium density residential
- High density residential
- Pine forest
- Shrubland with dispersed pine
- Scrubland
- Shrubland
- Abandoned fields to pine forest
- Abandoned fields to shrubland with dispersed pine
- Abandoned fields to scrubland
- Abandoned fields to shrubland
- Ravine vegetation
- Pine forest plantation
- Dry crops
- Irrigated crops
- Greenhouses
- Bare soil or degraded land
- Landfill and mineral extraction sites

LU/LC changes
Municipalities

- Water bodies
- Bare soil or ground
- Artificial surfaces
- Non-irrigated arable land
- Irrigated arable land
- Woodland
- Shrubland/herbaceous



AQUADAPT

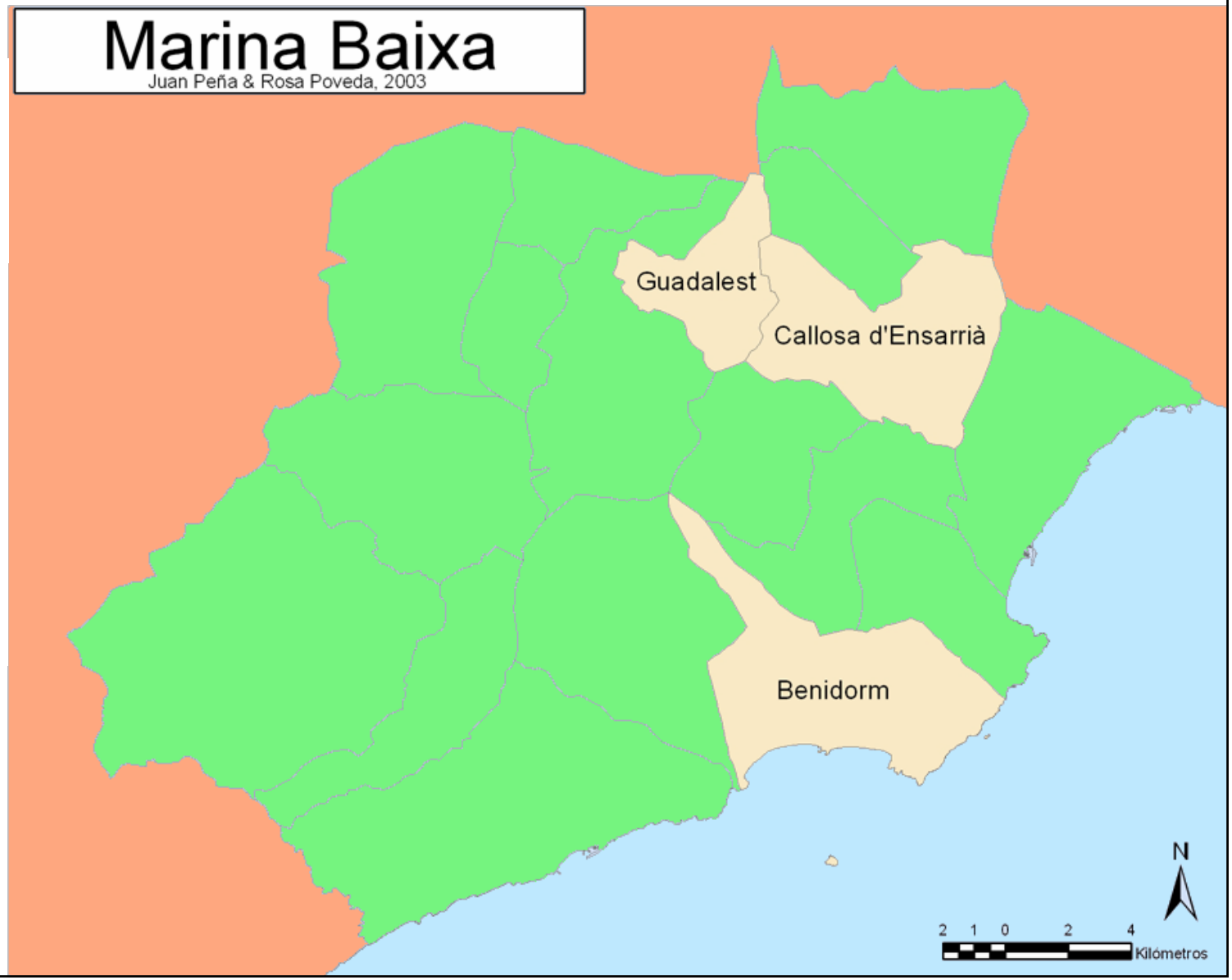
Universitat d'Alacant
Universidad de Alicante

3 municipalities

GUADALEST
180 hab.
16,10 Km^2

CALLOSA
7057 hab.
34,30 Km^2

BENIDORM
51.873 hab.
38,6 Km^2



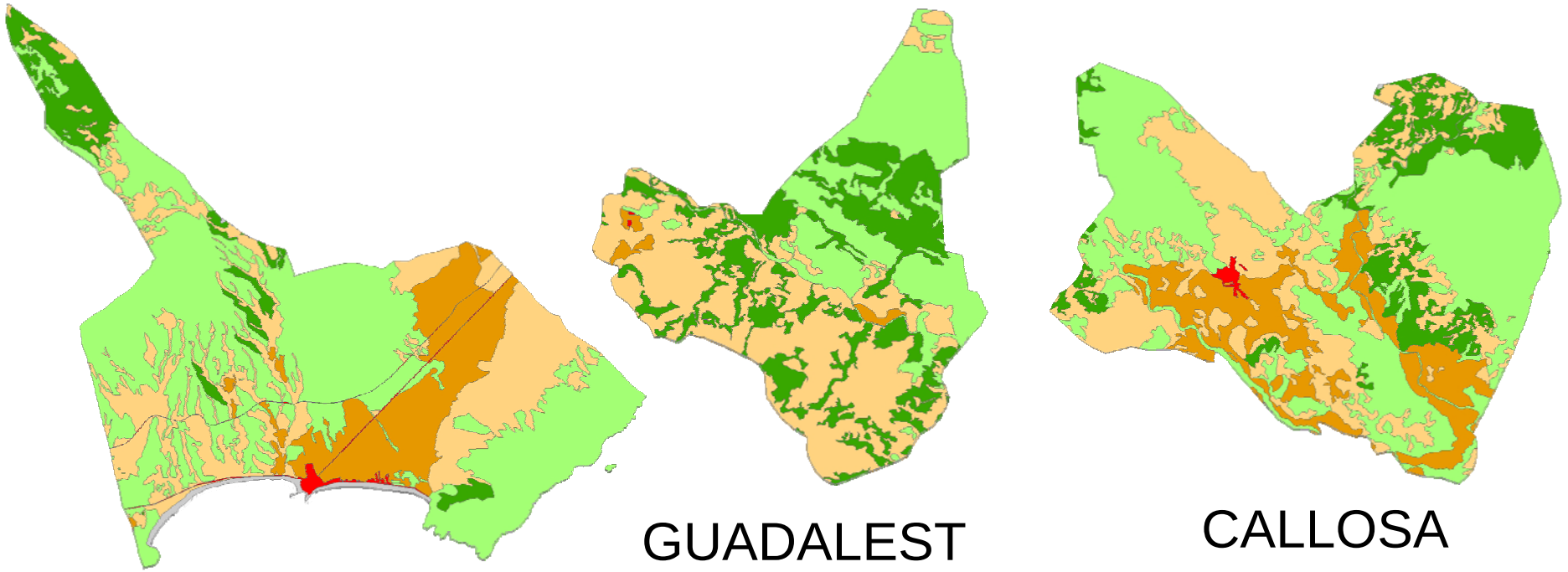
Universitat d'Alacant
Universidad de Alicante

Benidorm pattern of change

Guadalest pattern of change

Callosa d'Ensarrià pattern of change

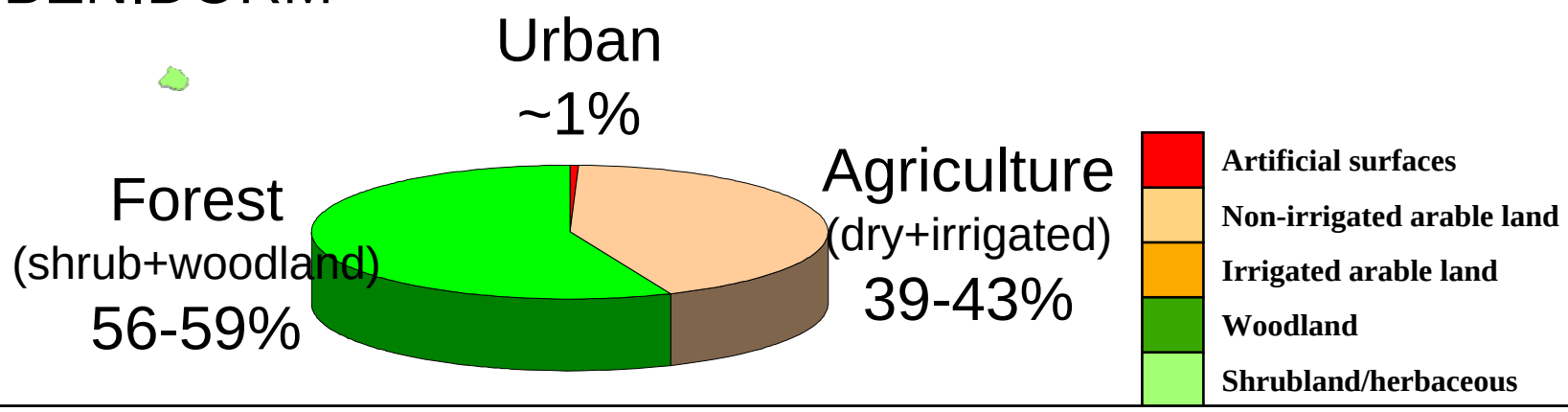
Similar LU/LC in 1956



BENIDORM

GUADALEST

CALLOSA



Landscape change

1956

Urban
~1%

Forest
56-59%

Agriculture
39-43%

Forest
54%

Urban
37%

Agriculture
9%

Urban
2%

Agriculture
30%

Forest
40%

Urban
3%

Agriculture
57%

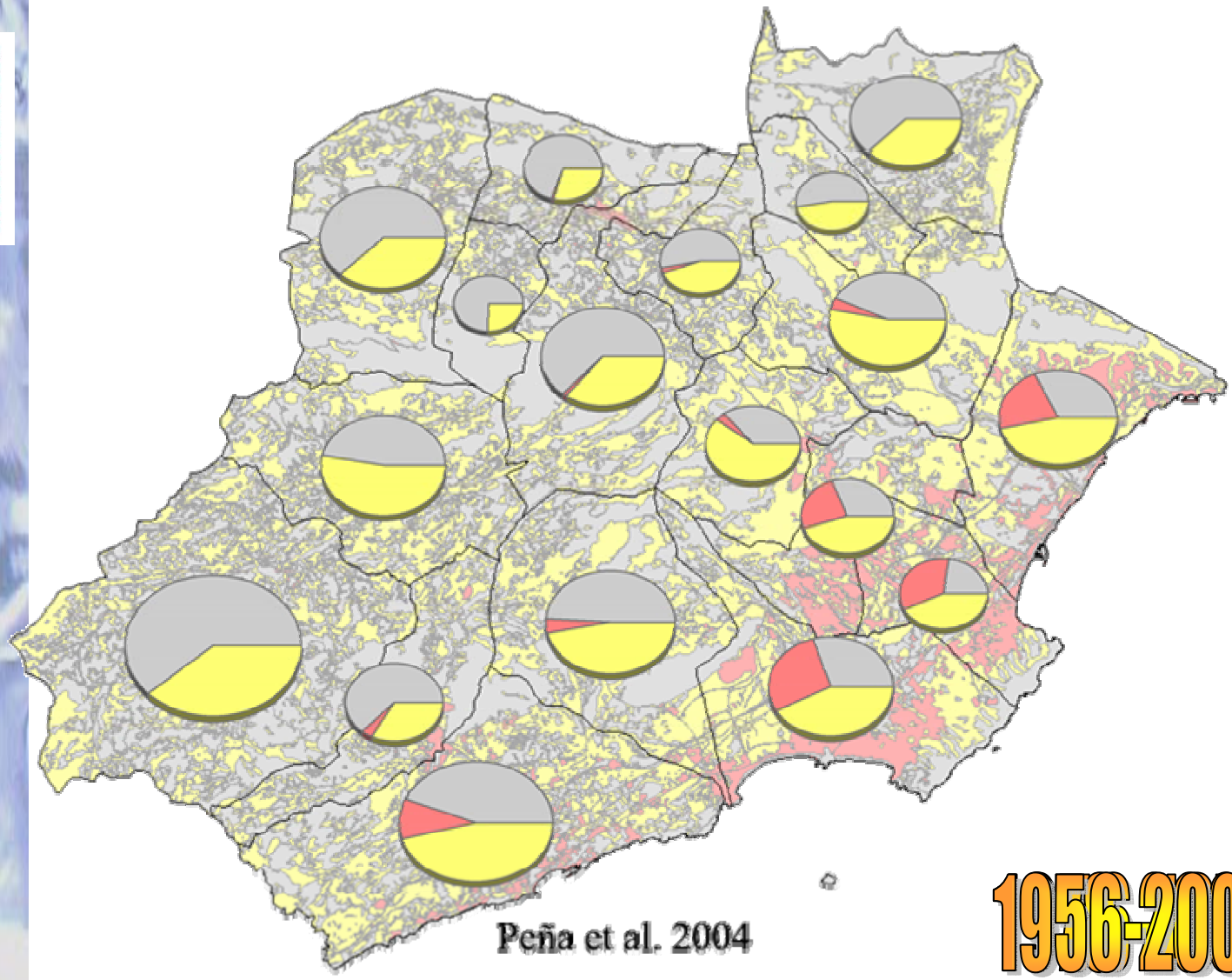
2000

BENIDORM

GUADALEST

CALLOSA

Irreversibility of the changes



Universitat d'Alacant
Universidad de Alicante

TRANSITIONS
Markovian transition matrix analysis:

- *Ecological sustainability*: the tendency of a system or process to be maintained or preserved over time without loss or decline.

Universitat d'Alacant
Universidad de Alicante

Markovian transition matrix analysis

- Simple non-spatial landscape model analogous to the method of Markov-chain transition probabilities for each two-year combination of land use changes (1956-1978, 1978-2000 and 1956-2000). (Dale et al., 2002).

- We considered a set of subrogates of the ecological sustainability of the water management system:

  – ecological complexity and stability
  – ecosystem services (Costanza et al. 1997) provided as steady environmental returns of natural capital.

Universitat d'Alacant
Universidad de Alicante

Markovian transition matrix analysis:

- Ecosystem services and water use indicators are based on several parameters
  - vegetation biomass,
  - successional status,
  - irreversibility of change or the potential to reverse a change,
  - variation in water consumption,
  - evaporation and evapo-transpiration of vegetation cover
  - land fragmentation (landscape analysis).

Universitat d'Alacant
Universidad de Alicante

Markovian transition matrix analysis: Environmental quality

- Transitions are then grouped in terms of the processes that the territory has experienced (urbanization, ecological succession, agriculture irrigation, degradation, etc.),

  - ❑aggradative,
  - ❑degradative,
  - ❑stationary (no change, retention probabilities)

Universitat d'Alacant
Universidad de Alicante

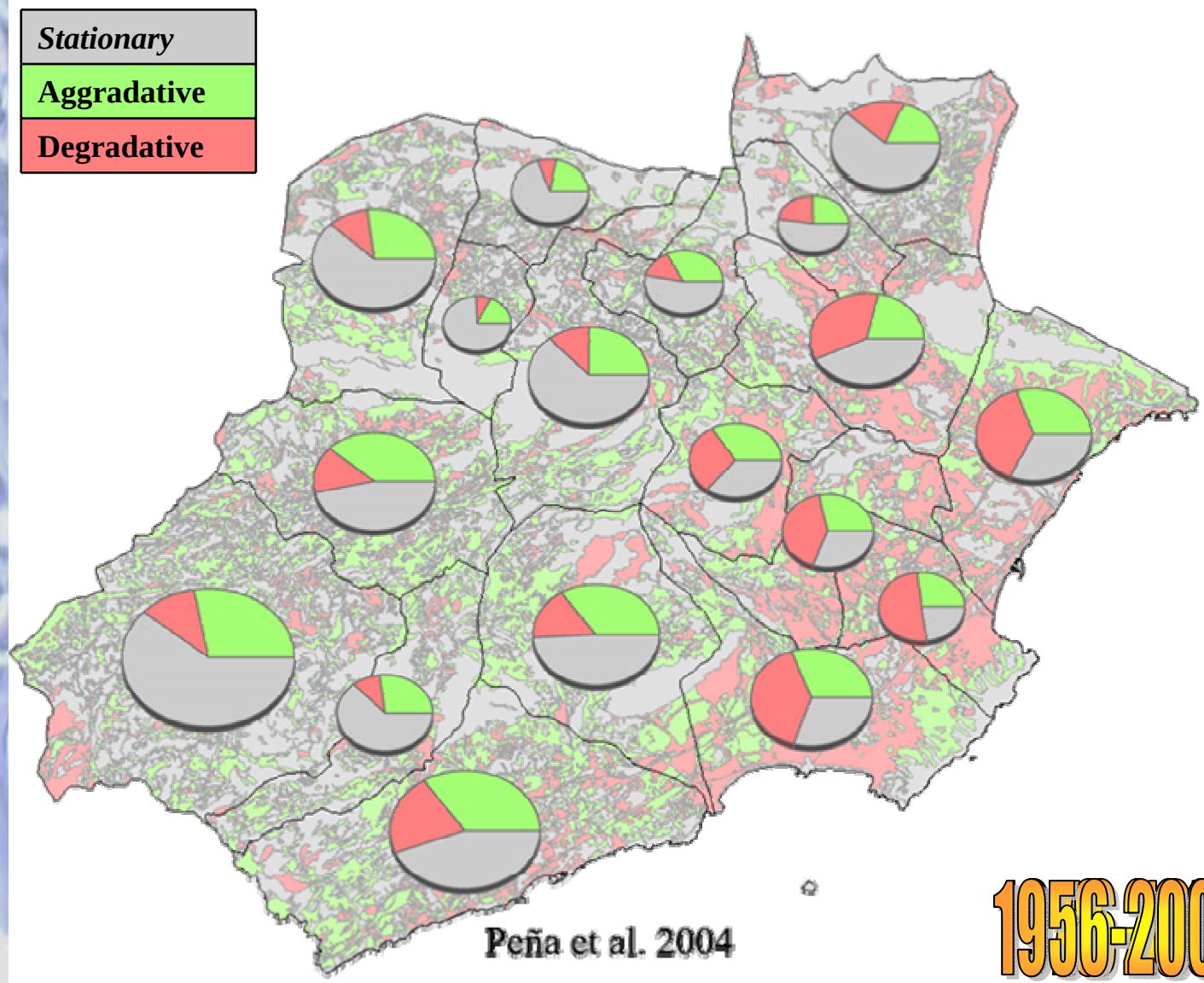
LU/LC categories qualitative markovian transition matrix

1956		2000						
		Water bodies	Bare soil or ground	Artificial surfaces	Non-irrigated arable land	Irrigated arable land	Woodland	Shrubland/ herbaceous
	Water bodies	*Stationary*	Aggradative	Degradative	Aggradative	Aggradative	Aggradative	Aggradative
	Bare soil or ground	Degradative	*Stationary*	Degradative	Degradative	Degradative	Aggradative	Aggradative
	Artificial surfaces	Aggradative	Aggradative	*Stationary*	Aggradative	Aggradative	Aggradative	Aggradative
	Non-irrigated arable land	Degradative	Degradative	Degradative	*Stationary*	Degradative	Aggradative	Aggradative
	Irrigated arable land	Degradative	Degradative	Degradative	Aggradative	*Stationary*	Aggradative	Aggradative
	Woodland	Degradative	Degradative	Degradative	Degradative	Degradative	*Stationary*	Degradative
	Shrubland/herbaceous	Degradative	Degradative	Degradative	Degradative	Degradative	Aggradative	*Stationary*

In terms of sustainable growth:

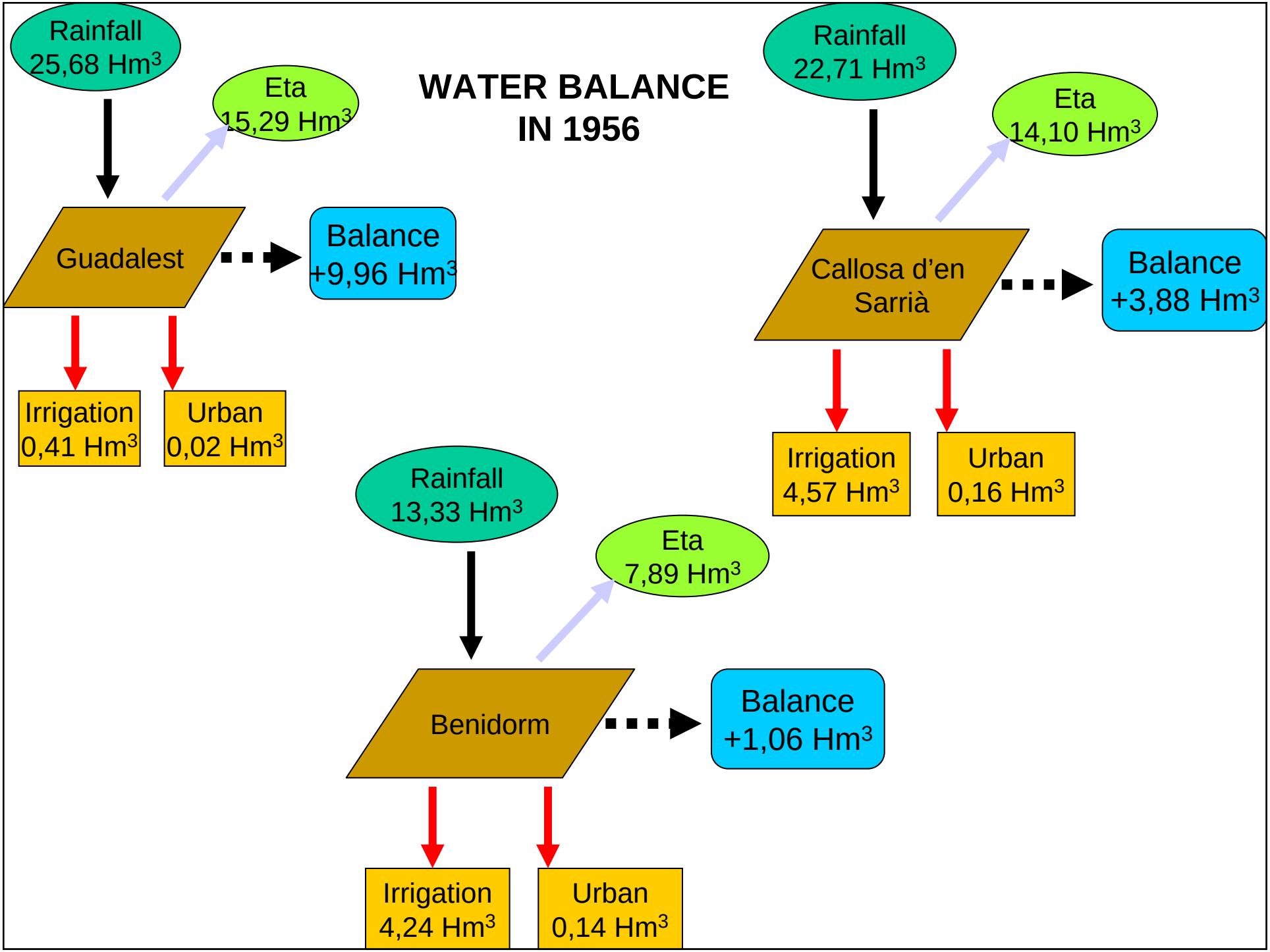
50.5%	*Stationary*	Changes between same ecological quality
29.2%	Aggradative	LU/LC more sustainable transitions
20.3%	Degradative	LU/LC less sustainable transitions

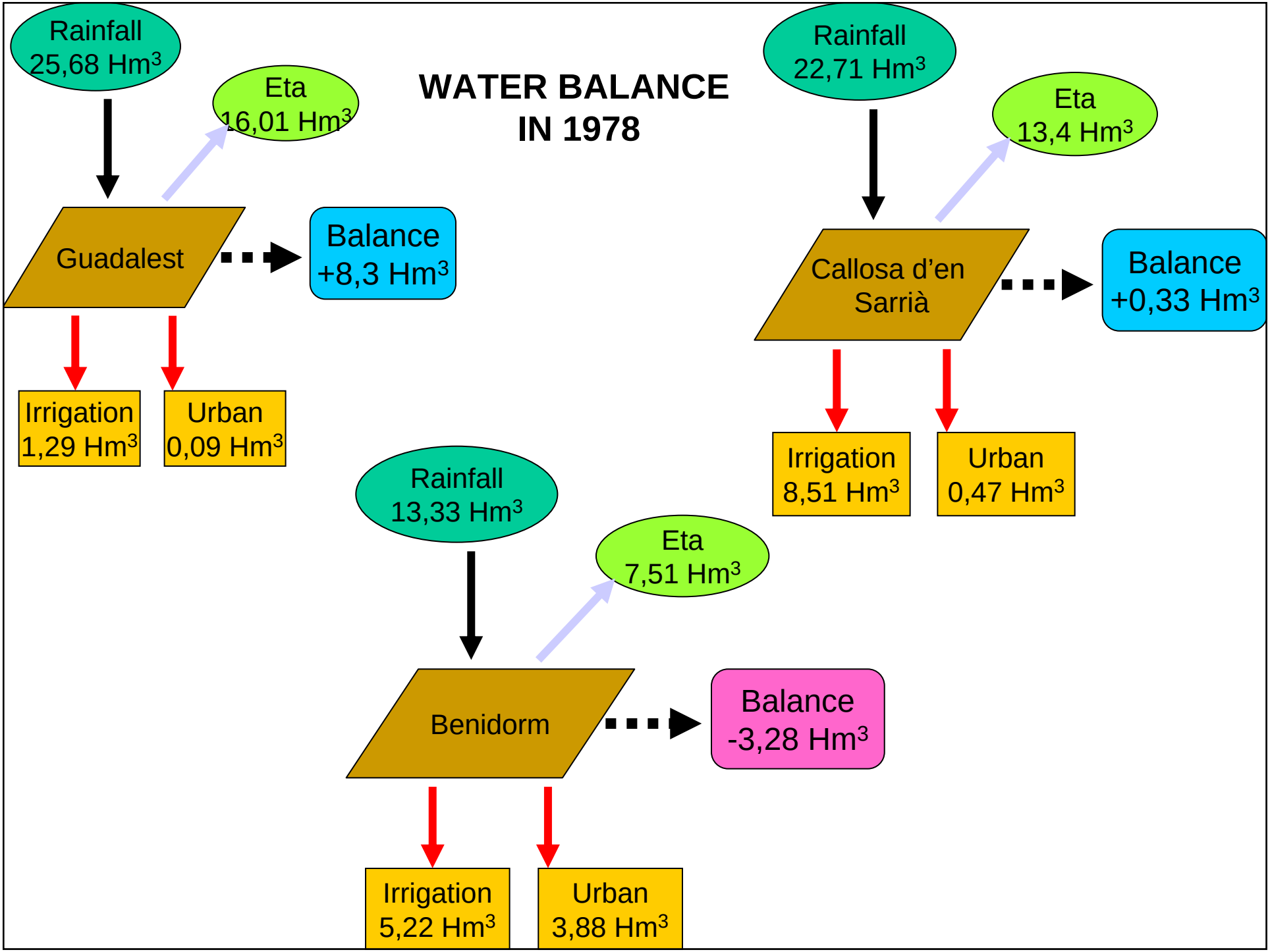
LU/LC categories qualitative markovian transition matrix

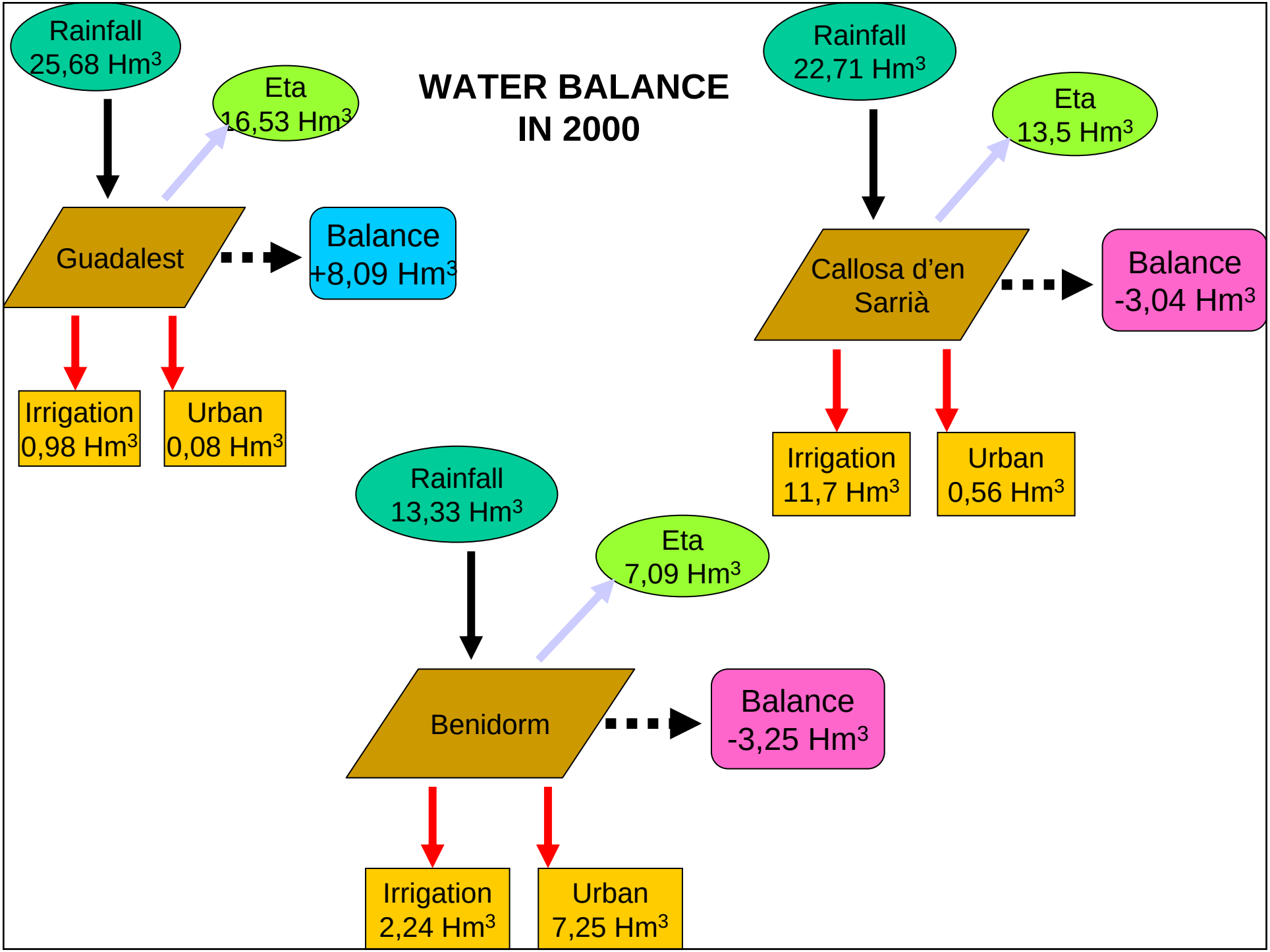


AQUADAPT

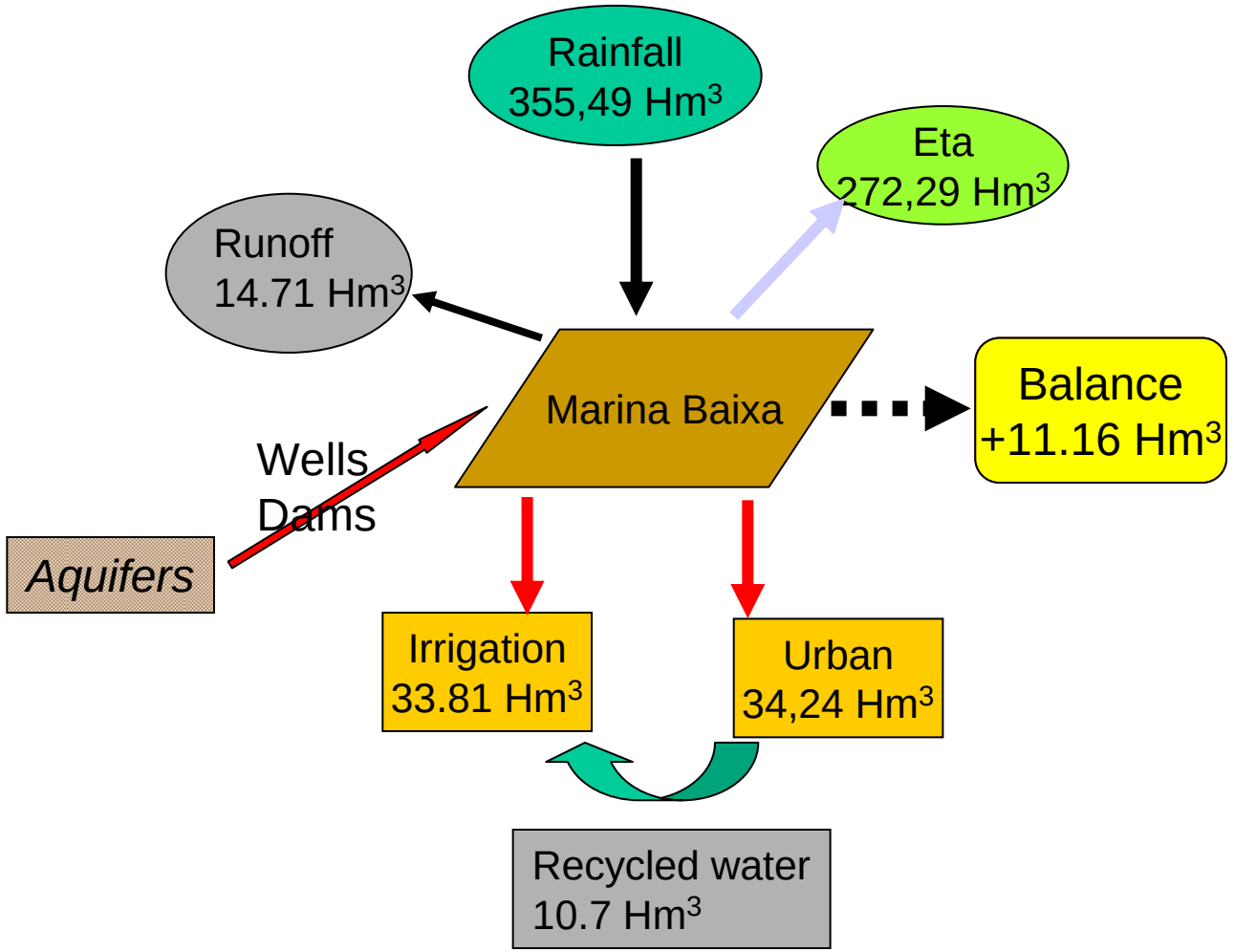
Universitat d'Alacant
Universidad de Alicante


WATER BALANCE
IN 1956
Rainfall
25,68 Hm3
Eta
15,29 Hm3
Guadalest
Balance
+9,96 Hm3
Irrigation
0,41 Hm3
Urban
0,02 Hm3
Rainfall
22,71 Hm3
Eta
14,10 Hm3
Callosa d'en
Sarrià
Balance
+3,88 Hm3
Irrigation
4,57 Hm3
Urban
0,16 Hm3
Rainfall
13,33 Hm3
Eta
7,89 Hm3
Benidorm
Balance
+1,06 Hm3
Irrigation
4,24 Hm3
Urban
0,14 Hm3


WATER BALANCE
IN 1978
Rainfall
25,68 Hm3
Eta
16,01 Hm3
Guadalest
Balance
+8,3 Hm3
Irrigation
1,29 Hm3
Urban
0,09 Hm3
Rainfall
22,71 Hm3
Eta
13,4 Hm3
Callosa d'en
Sarrià
Balance
+0,33 Hm3
Irrigation
8,51 Hm3
Urban
0,47 Hm3
Rainfall
13,33 Hm3
Eta
7,51 Hm3
Benidorm
Balance
-3,28 Hm3
Irrigation
5,22 Hm3
Urban
3,88 Hm3

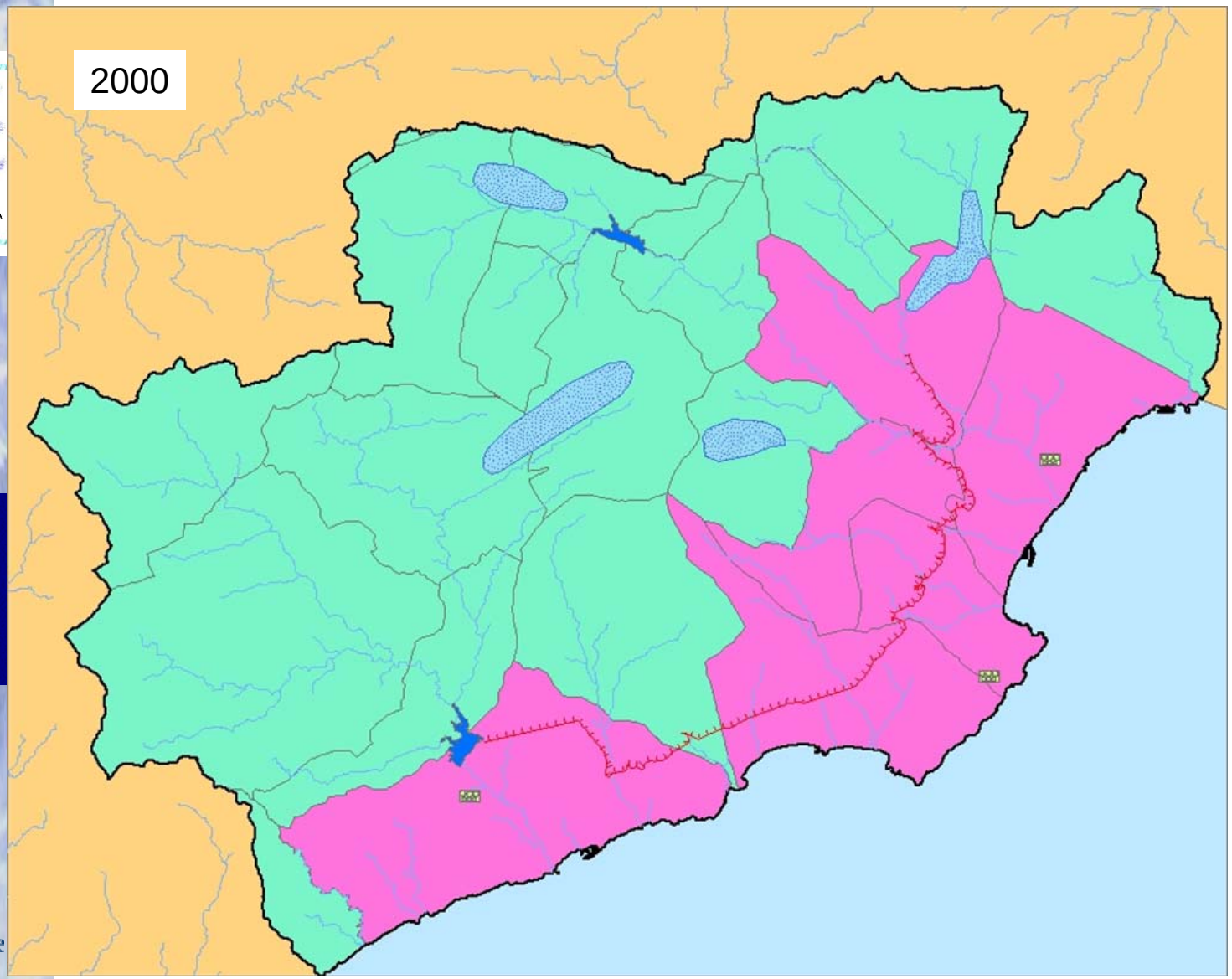

WATER BALANCE
IN 2000
Rainfall
25,68 Hm3
Eta
16,53 Hm3
Guadalest
Balance
+8,09 Hm3
Irrigation
0,98 Hm3
Urban
0,08 Hm3
Rainfall
22,71 Hm3
Eta
13,5 Hm3
Callosa d'en
Sarrià
Balance
-3,04 Hm3
Irrigation
11,7 Hm3
Urban
0,56 Hm3
Rainfall
13,33 Hm3
Eta
7,09 Hm3
Benidorm
Balance
-3,25 Hm3
Irrigation
2,24 Hm3
Urban
7,25 Hm3

Water balance of Marina Baixa in 2000



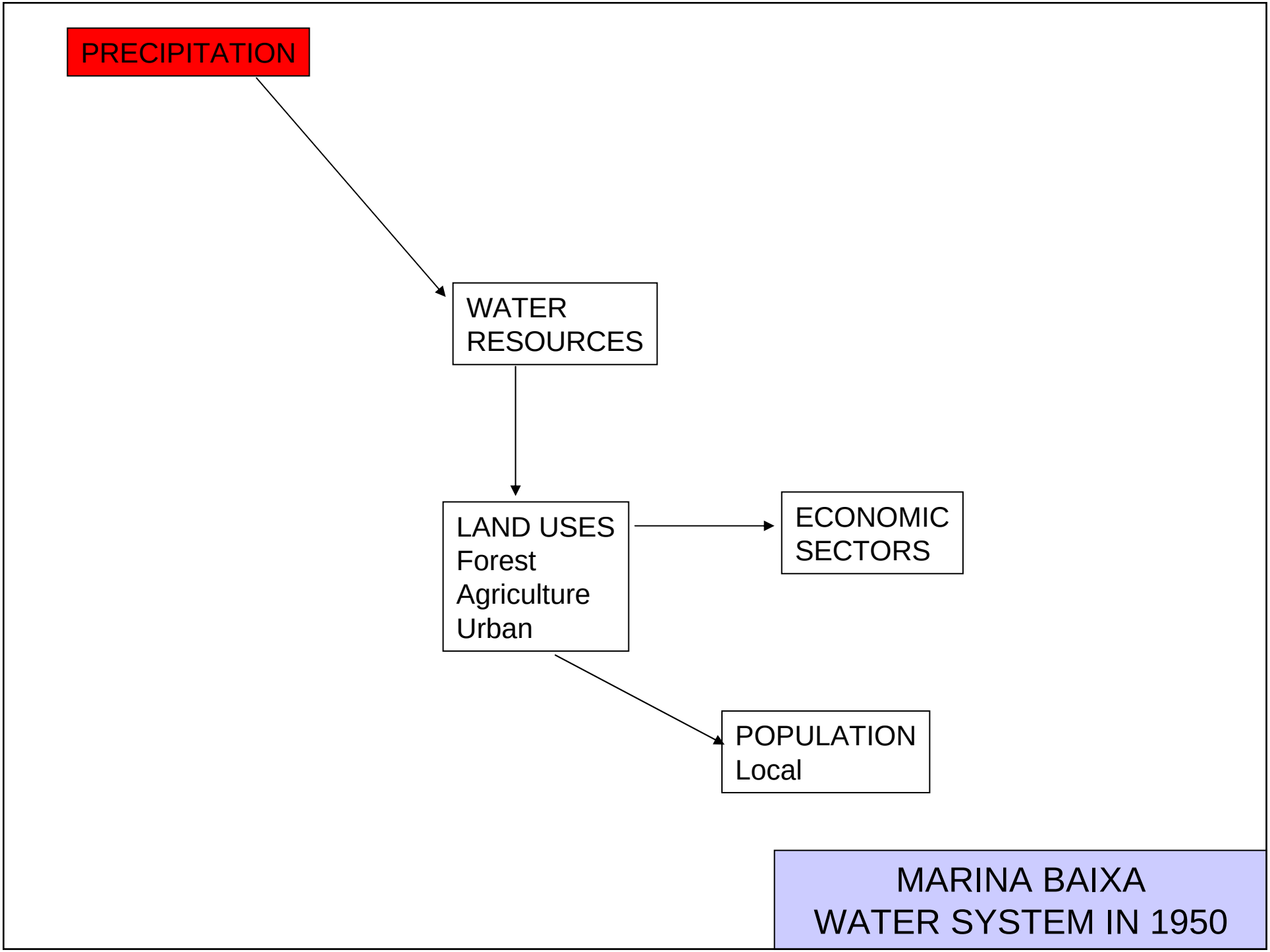
Universitat d'Alacant
Universidad de Alicante

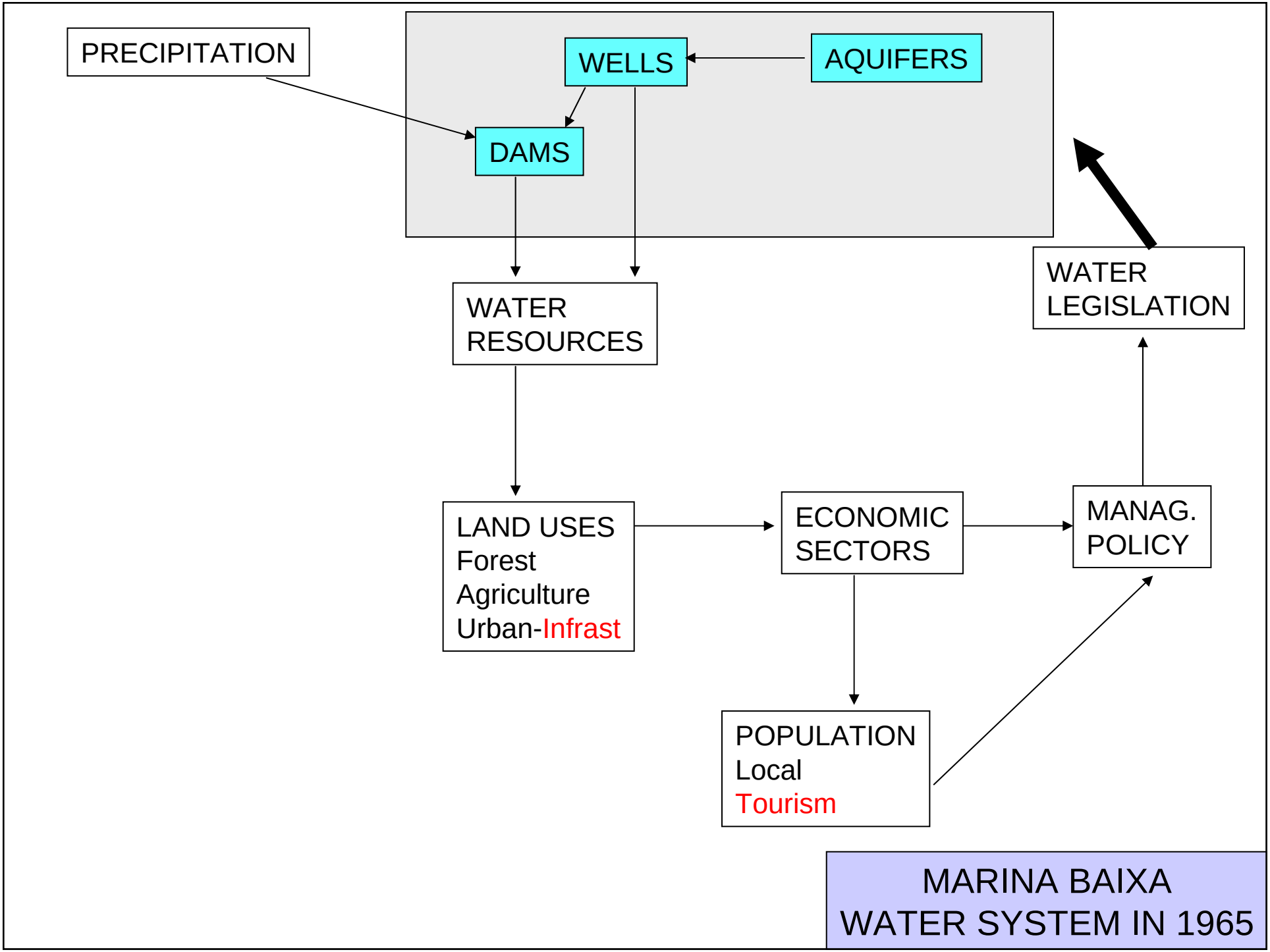
Water management dynamics

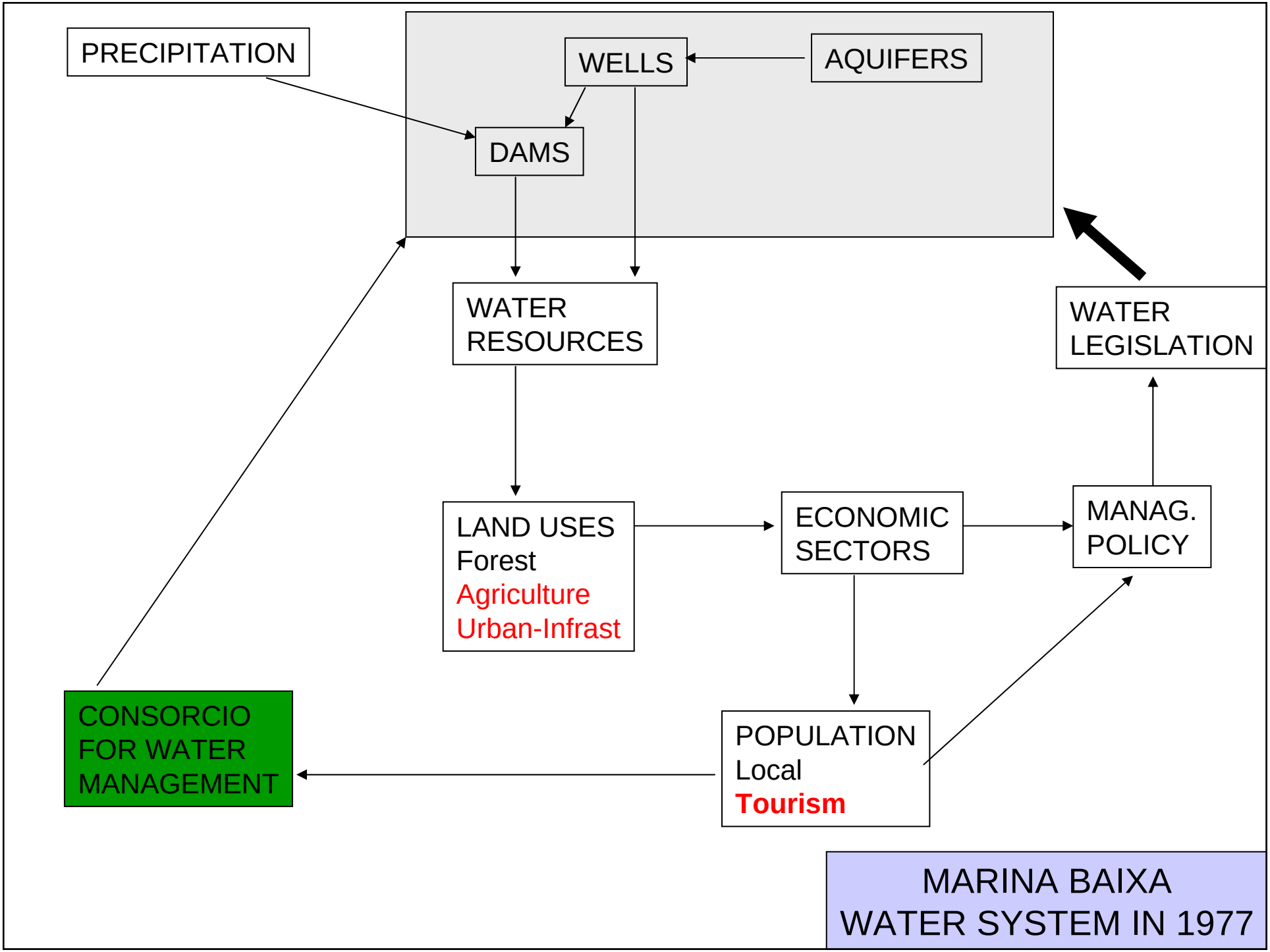


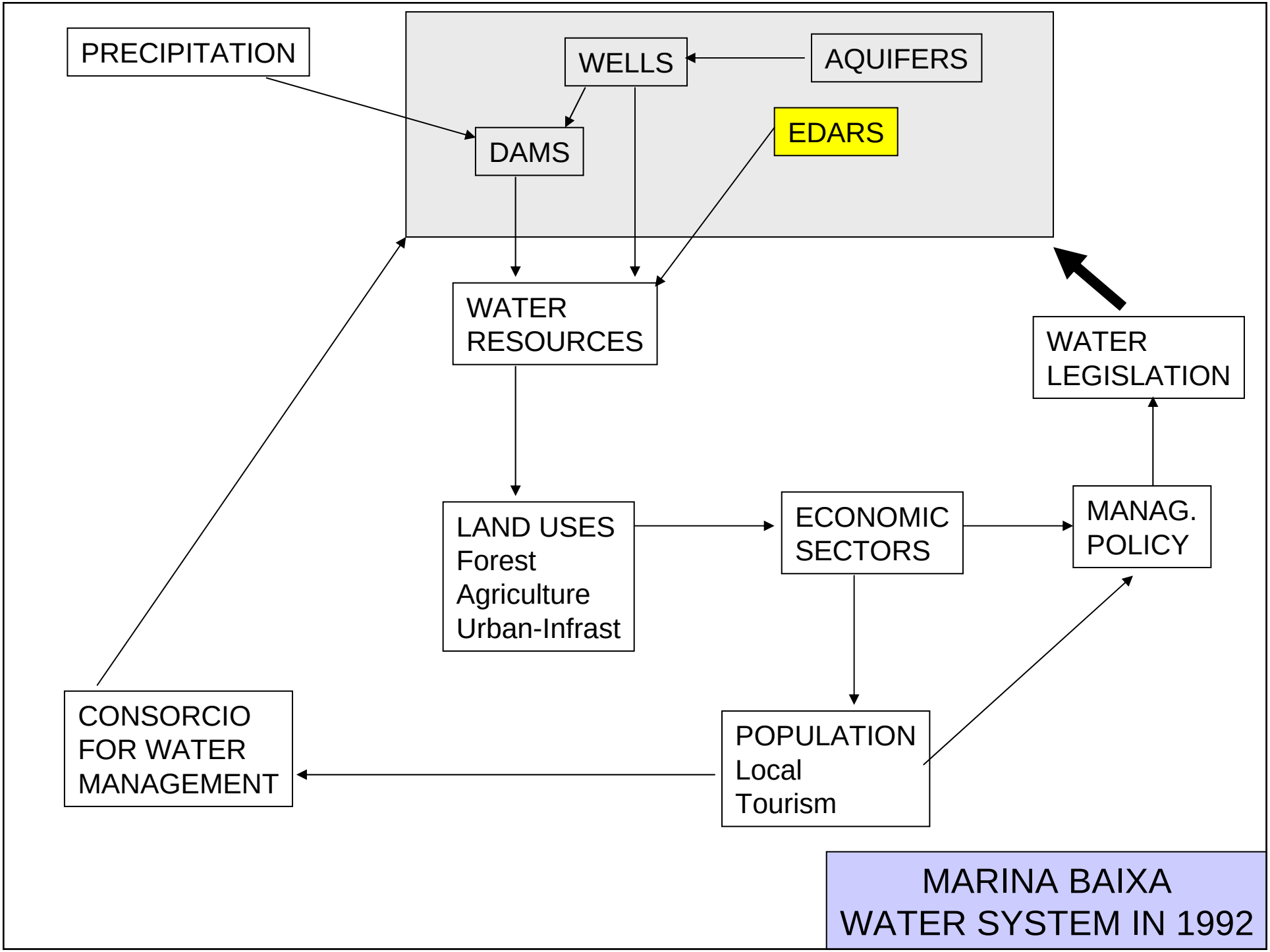
AQUADAPT

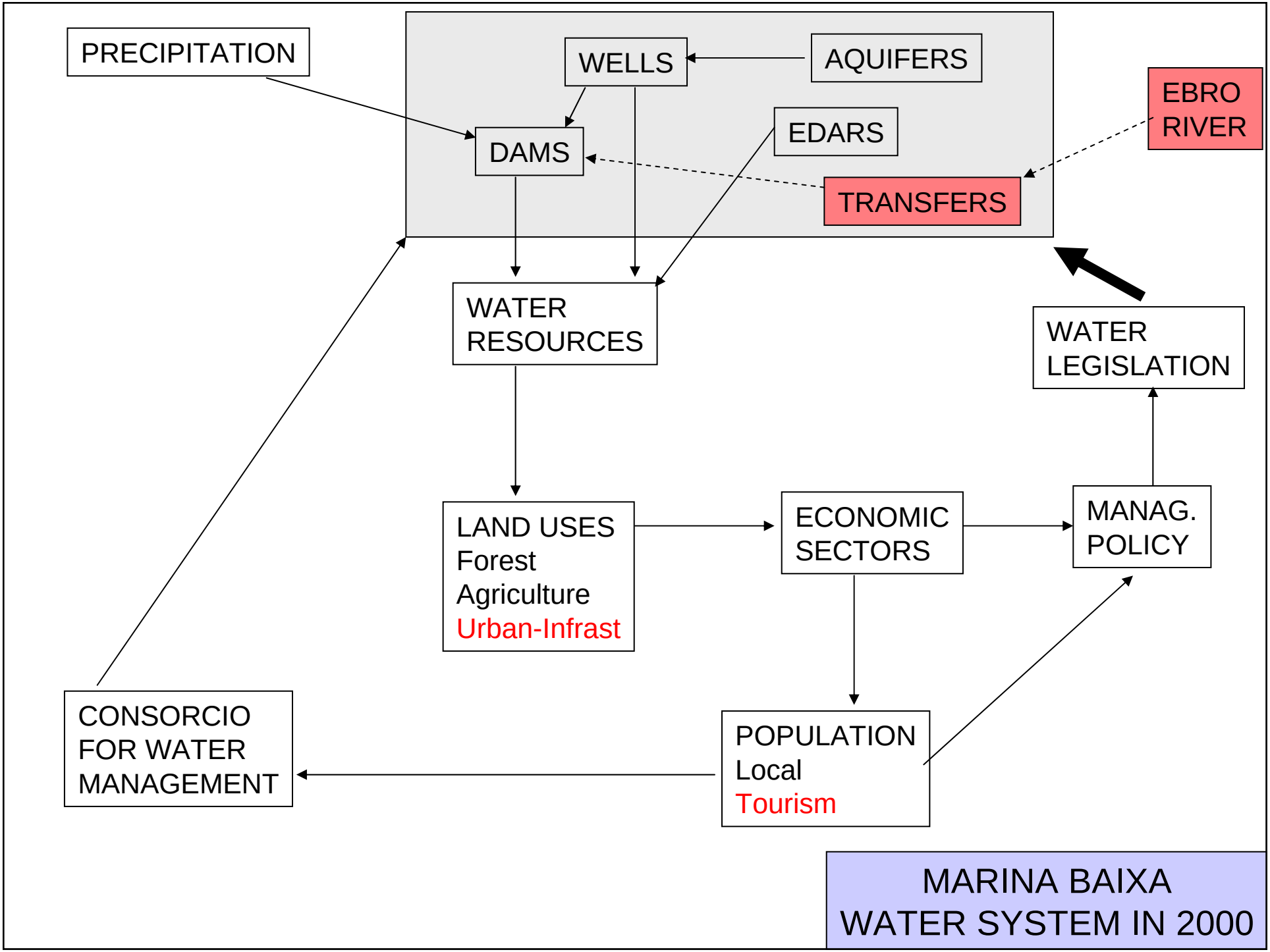
Universitat d'Alacant
Universidad de Alicante

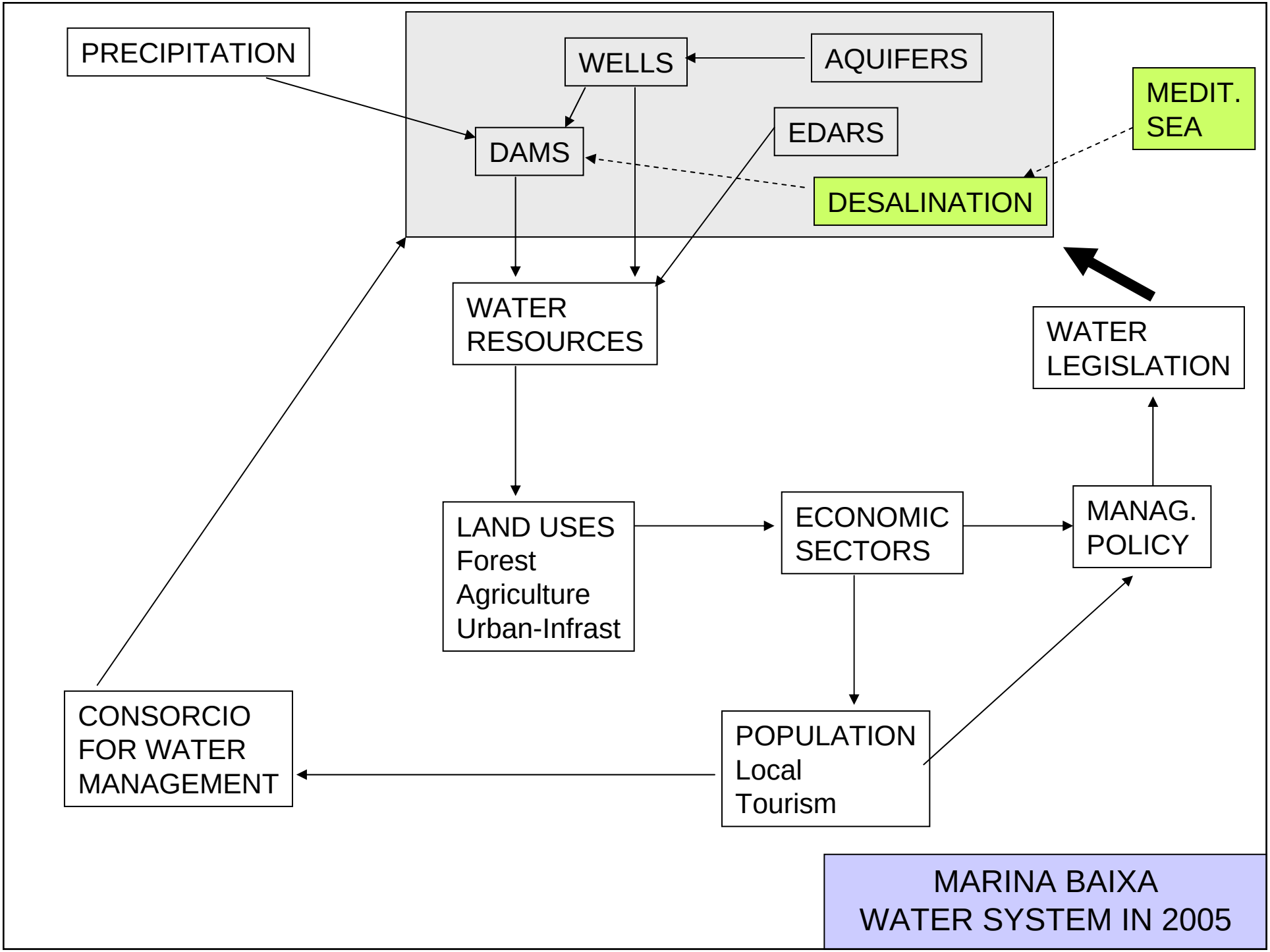

PRECIPITATION
WATER RESOURCES
LAND USES
Forest
Agriculture
Urban
ECONOMIC SECTORS
POPULATION
Local
MARINA BAIXA
WATER SYSTEM IN 1950


PRECIPITATION
WELLS
AQUIFERS
DAMS
WATER RESOURCES
WATER LEGISLATION
LAND USES
Forest
Agriculture
Urban-Infrast
ECONOMIC SECTORS
MANAG. POLICY
POPULATION
Local
Tourism
MARINA BAIXA
WATER SYSTEM IN 1965


PRECIPITATION
WELLS
AQUIFERS
DAMS
WATER RESOURCES
WATER LEGISLATION
LAND USES
Forest
Agriculture
Urban-Infrast
ECONOMIC SECTORS
MANAG. POLICY
CONSORCIO FOR WATER MANAGEMENT
POPULATION
Local
Tourism
MARINA BAIXA
WATER SYSTEM IN 1977


PRECIPITATION
WELLS
AQUIFERS
DAMS
EDARS
WATER RESOURCES
WATER LEGISLATION
LAND USES
Forest
Agriculture
Urban-Infrast
ECONOMIC SECTORS
MANAG. POLICY
CONSORCIO FOR WATER MANAGEMENT
POPULATION
Local
Tourism
MARINA BAIXA
WATER SYSTEM IN 1992


PRECIPITATION
WELLS
AQUIFERS
EBRO RIVER
DAMS
EDARS
TRANSFERS
WATER RESOURCES
WATER LEGISLATION
LAND USES
Forest
Agriculture
Urban-Infrast
ECONOMIC SECTORS
MANAG. POLICY
CONSORCIO FOR WATER MANAGEMENT
POPULATION
Local
Tourism
MARINA BAIXA
WATER SYSTEM IN 2000


PRECIPITATION
WELLS
AQUIFERS
MEDIT. SEA
DAMS
EDARS
DESALINATION
WATER RESOURCES
WATER LEGISLATION
LAND USES
Forest
Agriculture
Urban-Infrast
ECONOMIC SECTORS
MANAG. POLICY
CONSORCIO FOR WATER MANAGEMENT
POPULATION
Local
Tourism
MARINA BAIXA
WATER SYSTEM IN 2005

Institutional System, 1956-1960

Spanish Government, Madrid

Júcar Catchment Confederation

Diputación de Alicante & Research Institutions

Benidorm | Callosa | Guadalest | + 15 Municipalities

Water users and associations | … | … | … | …

Law & policy

Information & claims

Embedded

Disembedded

Universitat d'Alacant
Universidad de Alicante

Institutional System, 1960-2004

Global forums and NGO's

EU

Spanish Government, Madrid

Júcar Catchment Confederation

Valencian Autonomous Community

Diputación de Alicante & Research Institutions

Consorcio de aguas, MB

Junta Central

Benidorm | Callosa | Guadalest | + 15 Municipalities

Commercial potable water suppliers

Local NGO's

Water users and associations | … | … | … | …

Law & policy

Information & claims

Embedded

Disembedded

AQUADAPT

Universitat d'Alacant
Universidad de Alicante

YEAR	WATER SOURCE	HOTELS IN MB	POPULATION	ACTIVITY SECTORS (%)	CLIMATIC EVENTS
1955	Precipitation			Agriculture 75%	Drought 4 months
				Industry 15%	in Benidorm
1956	Aquifers			Services 10%	
1957	Amadorio Dam	7 Hotels			
1960			41,375 Inhabit/local		Drought 6 months
					in Benidorm
1965	Guadalest dam	25 Hotels			Drought 5 m, Sella
1967			**Airport of Altet**		
1970			57,961 Inhabit/local	Agriculture 26%	Drought 6 months
			34,370 new houses	Industry 37%	in Bolulla
				Services 39%	Flood MB
1977	Ships water supply	149 hotels		EU support for irrigation	extreme drought
	CONSORCIO MB				
1981	Taibilla transfer	138 hotels	82,076 Inhabit/local		Extreme Drought ME
			65,638 new houses		
1984	EDAR Benidorm				Flood Benidorm
1987	EDAR Altea				Flood Benidorm, Alte
1989					Flood Benidorm, Alte
1990		PGOU Benidorm			Flood Benidorm
1991		158 hotels	108,623 Inhabit/local	Agriculture 6 %	Flood Benidorm
			90,950 new houses	Industry 23 %	Drought 4 months
				Services 71%	
1992	EDAR Vila Joiosa			PAC	Flood Altea, Benidor

YEAR	WATER SOURCE	HOTELS IN MB	POPULATION	ACTIVITY SECTORS (%)	CLIMATIC EVENTS
1994	Irrigation communities				Flood Altea Drought in MB
1995	National Plan for Waste water				Flood Altea
1996	EDAR Confrides EDAR Tárbena	136 hotels		First national irrigation Plan	Torrential rains
1997				First cartography of floods risk zones	Torrential rains
1998	EDAR Finestrat EDAR Sella EDAR Relleu EDAR Bolulla				
1999	Chanel Rabasa-Amadorio				Drought 6 months in MB
2000	Hydrologic National Plan				Drought 4 months in MB
2001	EDAR Guadalest	138 hotels	109,651 Inhabit/local 125,088 new houses	Agriculture 4 % Industry 21 % Services 75%	Floods in MB
2005	Desalination				

Conclusions

- Municipalities situated in more coastal positions showed high proportions of degradative transitions due to a higher degree of irreversibility of the transformations of the landscape .
- Adaptive and reactive responses had been appeared in a co-dynamic processes
- It would seem salient to assume that there exists a definite link between unsustainable and exponential land-use change and water transfers.
- Tourism and urban development are not linked with water availability
- The result of which appears to have a negative impact on the social adaptive capacity of the human population in MB, to adapt to changes in their water using culture.
- The trajectory of the water governance process is difficult to alter because the water management system is 'locked in' to a path that supports exponential land-use change that is promoted by water transfers that are currently administered by institutions that have emerged to fulfill this role.
- There is a complex institutional system on water management, with different administration levels and low coordination.
- It can be assumed that if there is evidence of resilience and adaptive capacity in the water governance process, it is most likely to be in the embedded institutions.

Universitat d'Alacant
Universidad de Alicante