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# **Principles of Land Resources Evaluation**

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# Motivation

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- Land provides a resource
- Land use is *affected by* the resource
  - opportunities, constraints
- Land use *affects* the resource
  - sustainability, degradation, improvement
- Objective is to *match*:
  - *land use* with the *land resource*



# FAO Framework for Land Evaluation

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- **3 levels**
  - Framework, Guidelines, Evaluations
- **Framework 1976**
- **Guidelines 1980's**
  - rainfed & irrigated agriculture
  - forestry
  - steepplands, extensive grazing



# FAO Framework - principles - 1

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- Evaluate *land areas* for a set of *specific uses*, each with their own requirements
- *Suitability* is defined by objective criteria
  - productive
  - environmental
  - social
  - economic
- Land uses must be *sustainable*



# FAO Framework - principles - 2

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- **Various *relevant* and *feasible* options are compared**
  - decision-makers then decide among the options
- **Evaluations take into account the *context* of the area concerned**
  - physical, economic, social, political



# Definitions

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- **Land**
- **Land Use Type (LUT)**
- **Land Evaluation Unit (LEU)**
- **Land Use System (LUS)**



# Land

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- **An area of the earth's surface...**
  - . . . including all **reasonably stable**, or **predictably cyclic**, attributes of the biosphere vertically above and below this area . . .
  - . . . including those of the **atmosphere**, the **soil** and underlying **geology**, the **hydrology**,
  - the plant and animal populations, . . .
  - . . . and the results of past and present **human activity**, . . .





# Land (continued)

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- ...to the extent that these attributes exert a **significant influence** on **present and future uses** of the land by humans.
- **A geographic concept**
  - each land area is uniquely located in space and is defined by that location



# Land Use Type (LUT)

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- **A specific manner of occupying and using the land...**
  - with specified management methods...
  - ...in a defined technical and socio-economic setting.
- **It may involve any number of activities and products, as long as they form part of one system of management.**
- **Also called *Land Utilization Type***



# Determinants of a LUT

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- **All aspects of the use that might be affected by the land resource**
  - product(s); market(s)
  - technology: land preparation, harvest...
  - inputs: water, fertilizers, agro-chemicals...
  - source of power (esp. for tillage)
  - management techniques (e.g. type of irrigation, method for scheduling...)



# Land Evaluation Unit (LEU)

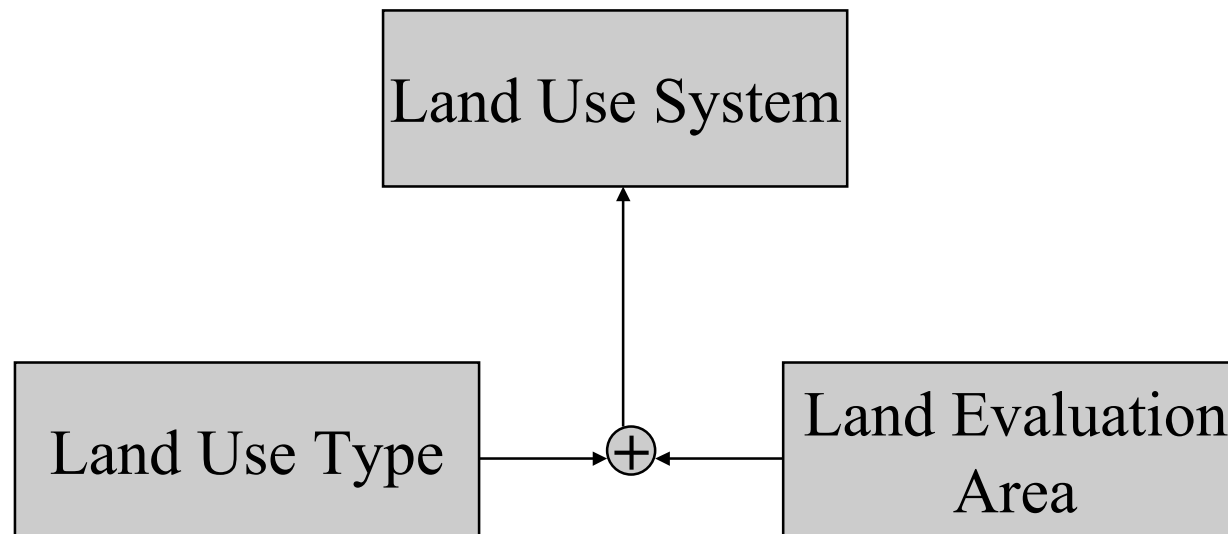
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- A specific area of land about which predictions will be made
- Topology
  - May be a *single* delineation (polygon or grid cell)
    - can evaluate *spatial aspects* in this case
  - May be a *set* of delineations (polygons) sharing the same characteristics (a ‘map unit’)



# Land Use System (LUS)

- A specific *Land Utilization Type* practised on a specific *Land Evaluation Unit*



# More Definitions

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- **Land Characteristic (LC)**
- **Land Quality (LQ)**
- **Land Use Requirement (LUR)**



# Land Characteristic (LC)

- ***A simple* attribute of a Land Evaluation Unit**
- ***Can be measured or estimated* in routine field, office laboratory work**
- **May be used to define one or more Land Qualities**
- **Examples**
  - site slope gradient
  - soil particle-size distribution with depth



# Land Quality (LQ) - 1

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- **A *complex* attribute of land...**
- **... which acts in a manner (more or less) *distinct* from the actions of other land qualities in its influence on the suitability of the land use system.**
- **Follows the time sequence of the land use**
- **Examples**
  - erosion hazard
  - moisture supply





# Land Quality (LQ) - 2

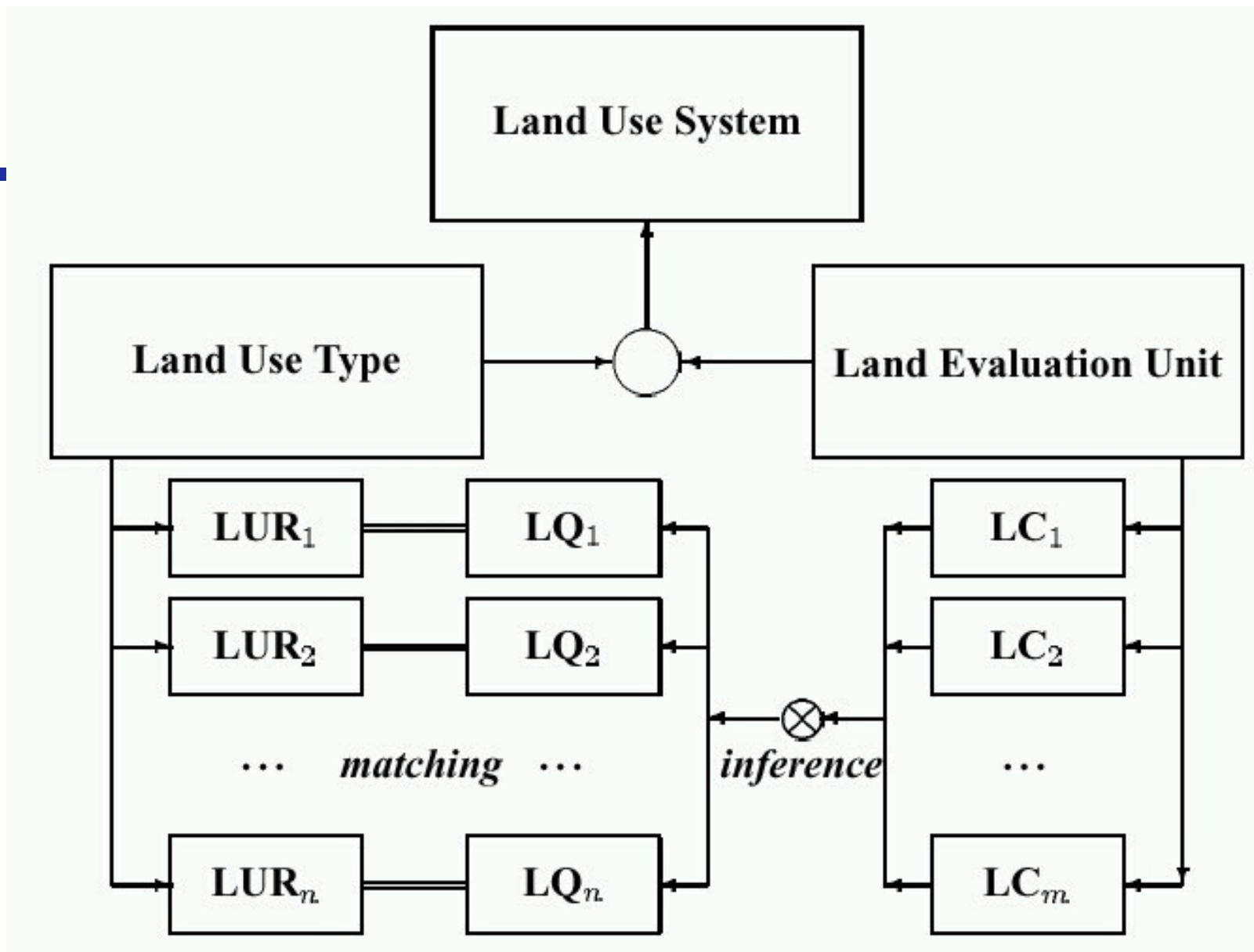
- The ability of the land to fulfil a specific LUR of a specific LUT
- The `supply' side of the land use - land area matching procedure.
- *Can not be measured or estimated in routine survey, so...*
- ... must be *inferred* from a set of *diagnostic LCs*
- **Example**
  - erosion hazard from rainfall intensity, topsoil silt & fine sand content, topsoil structure, slope gradient, ...



# Land Use Requirement

- A condition of the land necessary for successful and sustained implementation of a specific *Land Utilization Type*.
- The ‘demand’ side of the land use - land area matching procedure.
- Matches with a single “Land Quality”
- The *land use* requires ... the *land* supplies





# More Definitions

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- **Land Evaluation**
- **Suitability**
- **Sustainability**



# Land Evaluation

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- **“The prediction of land performance over time under specific uses”**
- **Key words:**
  - “prediction”
  - “performance”
  - “specific uses”
  - “over time”



# Suitability

- The ‘fitness’ of a given *Land Use System*
- i.e., the degree of its success if implemented
- Scales of measurement
  - classes (1 = best, ...,  $n$  = worst)
  - continuous index (e.g. 0 to 100)
  - yield or other output, on a continuous scale
  - economic metric
    - cost / benefit ratio, net present value, internal rate of return, gross margin...



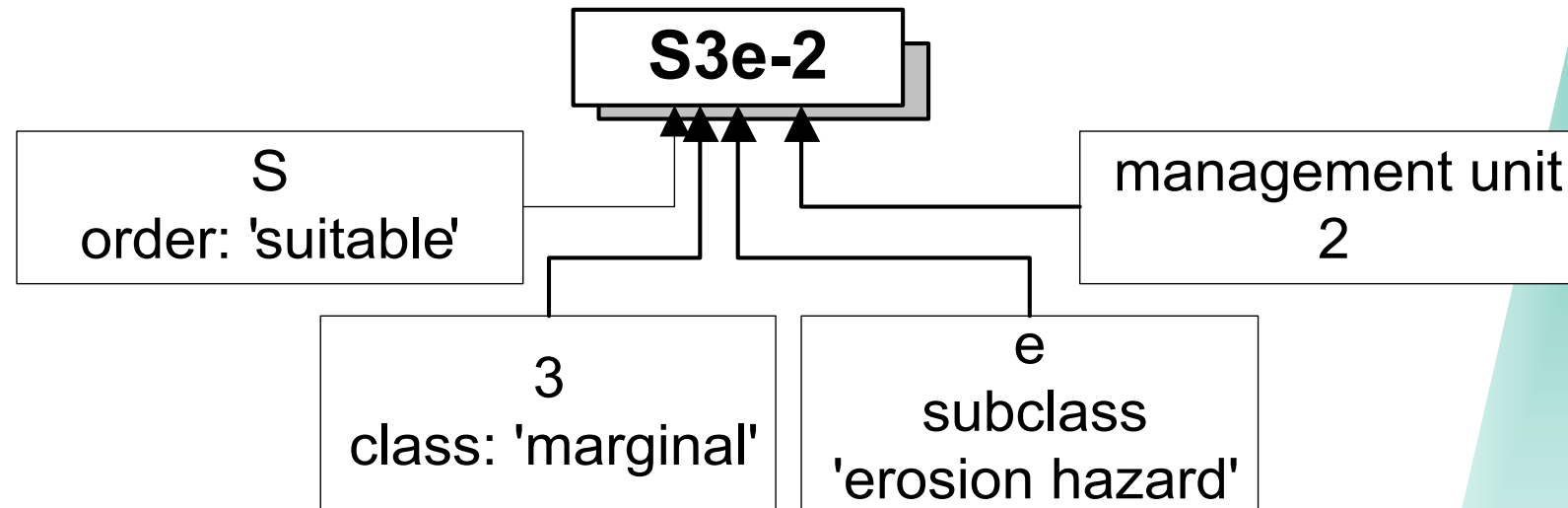
# Sustainability

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- **“The ability of a land use system to continue indefinitely at an acceptable level of performance, so long as its context does not change”**
- **Measurable (‘performance’) but only over time**
- **Indicators can be used to monitor (‘early warning’)**



# FAO suitability order, class, subclass, and unit



Orders: S, N

Classes: S1, S2, S3...; N1, N2





# FAO method

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- **Steps:**

- Define relevant *LUTs*
- Select *LURs* for each LUT
- Select *Diagnostic LC* for each LUR's corresponding LQ
- Define *diagnostic procedures*
- Evaluate severity levels of *LQ* from *Diagnostic LC*, to obtain *single factor ratings*
- Combine *factor ratings* to obtain *overall suitability* for the LUT



# Land Use Requirements

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- For the FAO method



# Groups of Land Use Requirements

- **A Agro-ecological**
  - A.1 Sufficiency of ecological factors for production
  - A.2 Constraints to production
- **B Management**
- **C Spatial**
- **D Land improvement**
- **E Conservation & environment**
- **F Social & political**
- **G Management constraints**
- **H Whole-area**

In Red: require spatial analysis



# A - Agro-ecological LUR - 1

- **Agro-climate (general)**

- A1.1 growing period
- A1.2 radiation
- A1.3 temperature
- A1.4 **moisture**
- A1.5 **oxygen**
- A1.7 air humidity

- **Agro-climate at specific points in the cycle**

- A2.1 **establishment conditions**
- A2.2 **rooting conditions**
- A2.3 maturity conditions

**In Red: soil information especially relevant**



# A - Agro-ecological LUR - 2

- **Soil conditions**

- A3.1 **nutrient sufficiency**
  - A3.1.1 **nutrient supply**
  - A3.1.2 **nutrient retention**
- A3.2 **salinity**
- A3.3 **sodicity**
- A3.4 **soil toxicities**, including direct effects of pH

- **Agro-environment**

- A4.1 **diseases, pests, weeds**



# A - Agro-ecological LUR - 3

## ● Natural hazards

- A5.1 flood hazard
- A5.2 **physiographic hazards - landslide**
- A5.3 climatic hazards
  - A5.3.1 fire
  - A5.3.2 frosts
  - A5.3.3 wind

## ● Animal production

- A6.1 drinking water quantity and quality
- A6.2 **minerals**



# B - Management

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- **B1 water management**
  - B1.1 water availability for irrigation
  - B1.2 water quality (short-term)
  - B1.3 **water application for irrigation**
  - B1.4 **drainage**
- **B2 tillage**
- **B3 pre-harvest management**
- **B4 harvest management**
- **B5 post-harvest management**
- **B6 storage and processing**
- **B7 mechanization**



# C - Spatial

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- **C1 transport costs**
- **C2 adjacency to other uses**
- **C3 distance from other uses**
  - C3.1 proximity
    - closer is better
  - C3.2 separation
    - further is better
  - C3.3 ideal distance
- **C4 accessibility to the production unit**
- **C5 access within the production unit**
- **C6 shape and size of the parcel**





# D - Land Improvement

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- **D1 clearing**
- **D2 land shaping**
- **D3 flood protection**
- **D4 drainage**
- **D5 levelling**  
(topography)
- **D6 physical, chemical & organic ammendments**
- **D7 leaching**
- **D8 recuperation period**
- **D9 irrigation works**  
(construction)



# E - Conservation & Environment

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- **On-site (sustainability)**

- E1 prevention of salinity and sodicity
- E2 long-term water quality and control
- E3 erosion hazard
- E4 land degradation hazard
- E5 vegetation degradation hazard

- **Off-site (environmental issues)**

- E6 streamflow response
- E7 preservation of species (biodiversity)
- E8 environmental risks



# F - Social & Political

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- **F1 political entity**
- **F2 land tenure**
- **F3 farmer attitudes**
- **F4 labour availability**



# G - Management constraints

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- **G1 seasonality  
(opportunity)**



# H - Whole-area

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- **constraints over the entire Land Evaluation Area or Land Planning Area**
  - maximum, minimum production
  - maximum, minimum area



# Selection of LURs

- ***Important*** for use (i.e., have an effect)
- **Existence of *critical values*** in study area
  - Sub-optimum...
  - ... varying over the area
  - *variables* become *constants*
- **Data to evaluate are available**
  - diagnostic Land Characteristics
- **Knowledge on how to evaluate is available**
  - selection of diagnostic Land Characteristics



# Evaluation of Land Qualities

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- **Expert judgement**
  - Matching Tables
  - Decision Trees
- **Computation**
  - Empirical-statistical models
  - Dynamic models



# Example of Matching Table

Diagnostic  
LC's

Land Characteristic	Severity Level of the Land Quality			
	<i>s1</i> (optimum)	<i>s2</i> (moderate)	<i>s3/n1</i> (marginal)	<i>n2</i> (impossible)
<b>texture/structure, class</b>	C-60s, SiCS, Co, SiCL, CL, Si, Sil, SC,L, SCL, SL	C+60v, C+60s, C-60v, LfS, LS	Cm, SiCm, LcS, fS, S	cS
<b>coarse fragments, volume %</b>	<15	<35	<55	>55
<b>soil depth, cm</b>	>50	>20	>10	<10
<b>CaCO<sub>3</sub>, %</b>	<25	<35	<50	>50
<b>Ca<sub>2</sub>SO<sub>4</sub>, %</b>	<6	<10	<20	>20

LUT: rainfed sorghum, low technology

LQ: Rooting conditions





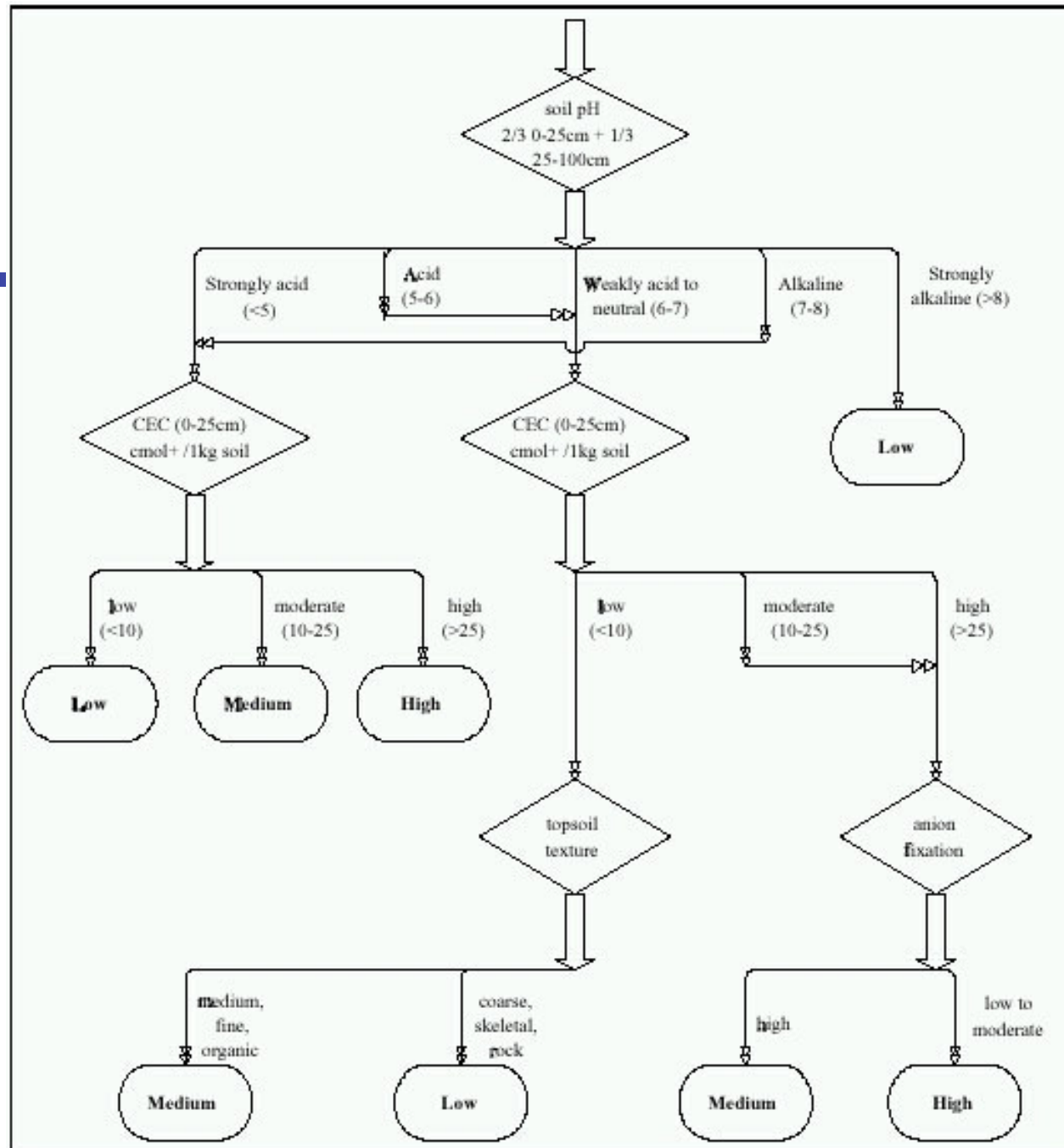
# Use of matching table

<i>texture/structure, class</i>	LfS
<i>coarse fragments, volume %</i>	20
<i>soil depth, cm</i>	100
<i>CaCO<sub>3</sub>, %</i>	45
<i>Ca<sub>2</sub>SO<sub>4</sub>, %</i>	5

Most limiting

Land Characteristic	Severity Level of the Land Quality			
	<i>s1</i>	<i>s2</i>	<i>s3/n1</i>	<i>n2</i>
<i>texture/structure, class</i>	C-60s, SiCS, Co, SiCL, CL, Si, Sil, SC,L, SCL, SL	C+60v, C+60s, C-60v, <b>LfS</b> , LS	Cm, SiCm, LcS, fS, S	cS
<i>coarse fragments, volume %</i>	<15	<b>20</b> <35	<55	>55
<i>soil depth, cm</i>	<b>100</b> >50	>20	>10	<10
<i>CaCO<sub>3</sub>, %</i>	<25	<35	<b>45</b> <50	>50
<i>Ca<sub>2</sub>SO<sub>4</sub>, %</i>	<b>5</b> <6	<10	<20	>20





# Combining Land Qualities

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- **Compute severity levels separately**
- **Combine with:**
  - Maximum limitation (most limiting)
  - Decision tree (allows compensation)
  - Arithmetic combination



# Models

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- **A representation of reality**
- **Simulation of real processes**
- **Can ‘compute’ and thus make predictions**



# Classification of models

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- **Degree of computation**
    - qualitative to quantitative
  - **Descriptive complexity**
    - empirical to mechanistic
  - **Level in the organizational hierarchy**
    - molecular to continental
- (from Hoosbeek & Bryant, *Geoderma*, 55:183–210, 1992)



# Levels of Knowledge

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- **K1 user expertise**
- **K2 expert knowledge**
- **K3 generalized holistic models**
- **K4 complex holistic models**
- **K5 complex models of system components**

(from Bouma, *Geoderma*, 78:1–12, 1997)



# Holistic vs. reductionist evaluation

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- **Holistic**

- evaluate system as a whole
- interactions are explicitly built into model

- **Reductionist**

- evaluate system components separately
- combine these results
- interactions are ignored or simplified



# FAO method in this structure

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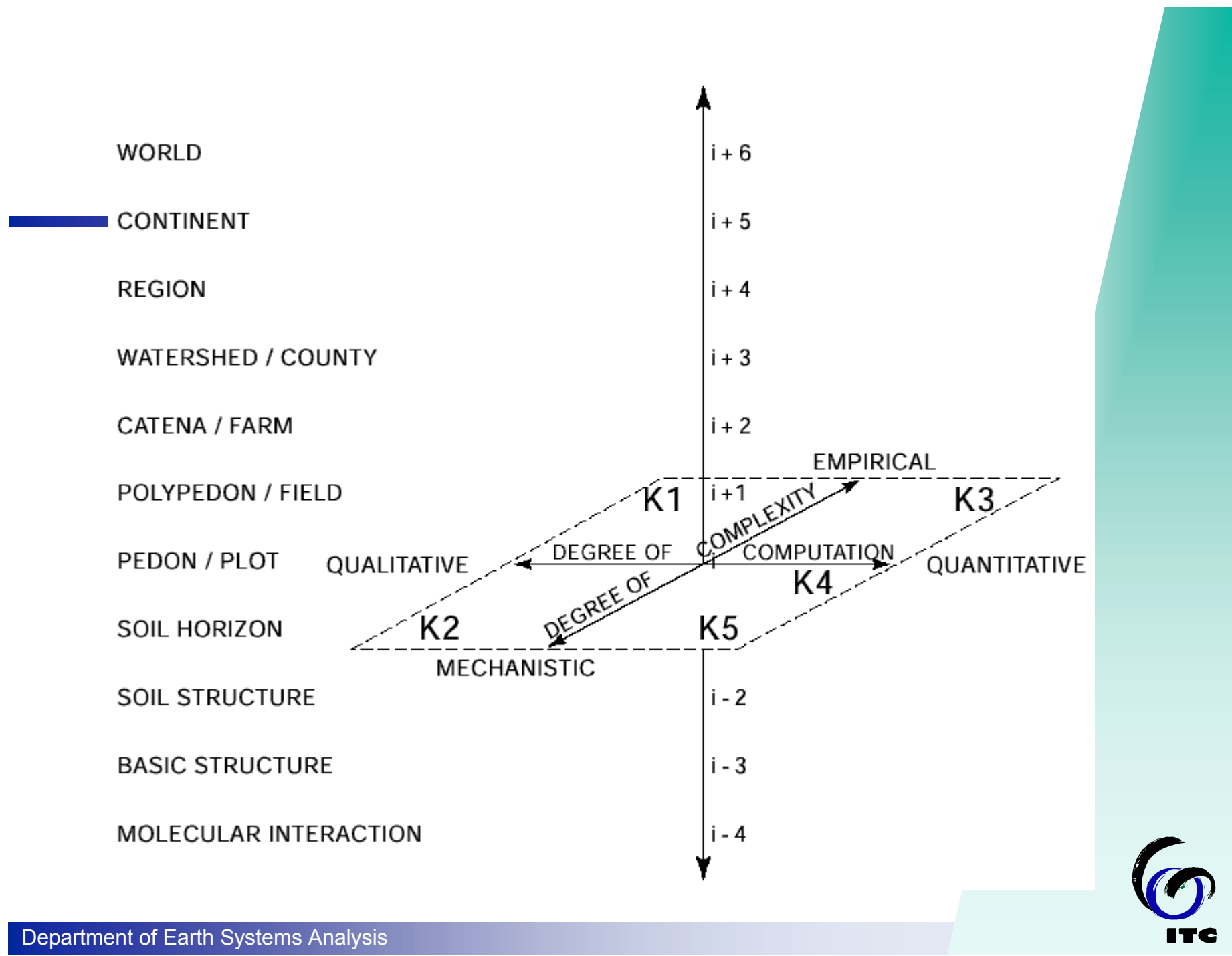
- **Knowledge levels**

- K2 (expert knowledge), and some simple models of system components

- **Reductionist**







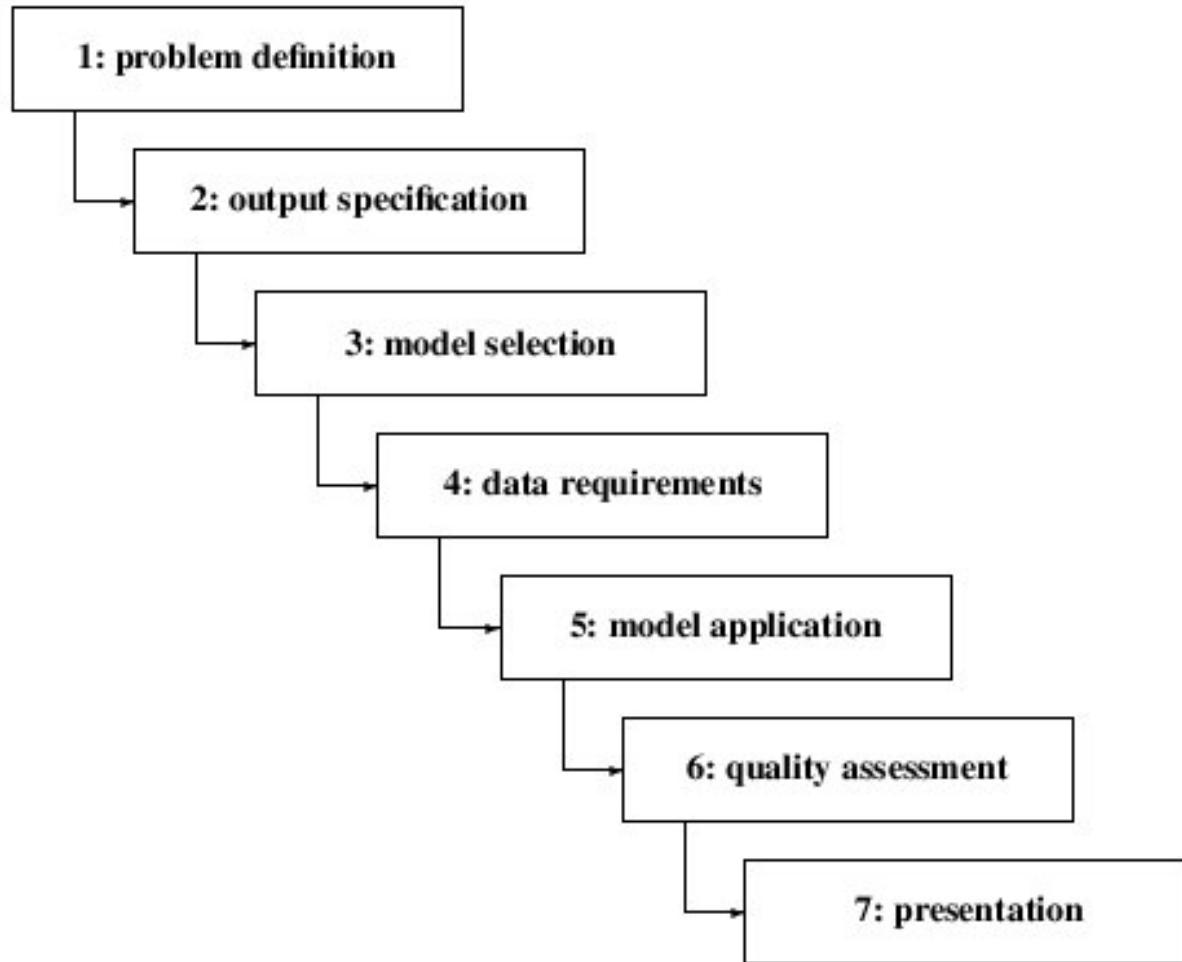
# New directions in land evaluation

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- **The research chain**
- **Demand-driven (client-centred) approach**
- **Stakeholder involvement**
- **Seive (stepwise refinement)**



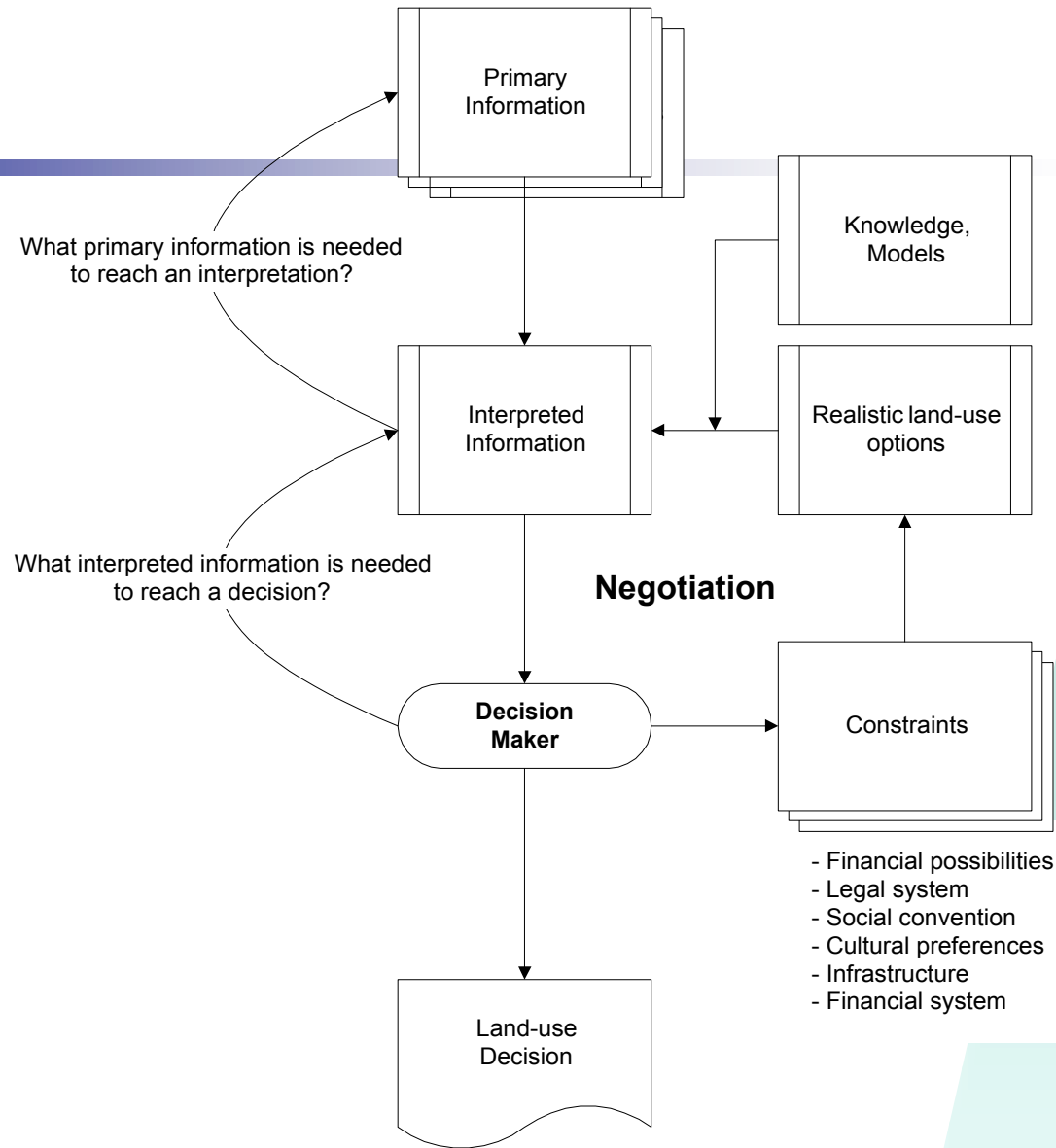
# The Research Chain



After Bouma (1999),  
“Land evaluation for  
landscape units”,  
Handbook of Soil  
Science, pp.E393-E412



# Demand-driven resource inventory & evaluation



# Seive (stepwise refinement)

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- **Increasingly detailed knowledge as suitable areas are identified**
  - 1 - eliminate completely unsuited areas with expert knowledge (K1 or K2)
  - 2 - calibrate system models (K4 or K5) in promising areas only
  - 3 - use system models to make quantified predictions in these areas

