Expert system for stored malting barley quality maintenance

Amadou Ndiaye

QualiGrain

http://www.bordeaux.inra.fr/qualigrain

Expert system for stored malting barley quality maintenance

Système expert de gestion de la qualité de l'orge de brasserie stockée
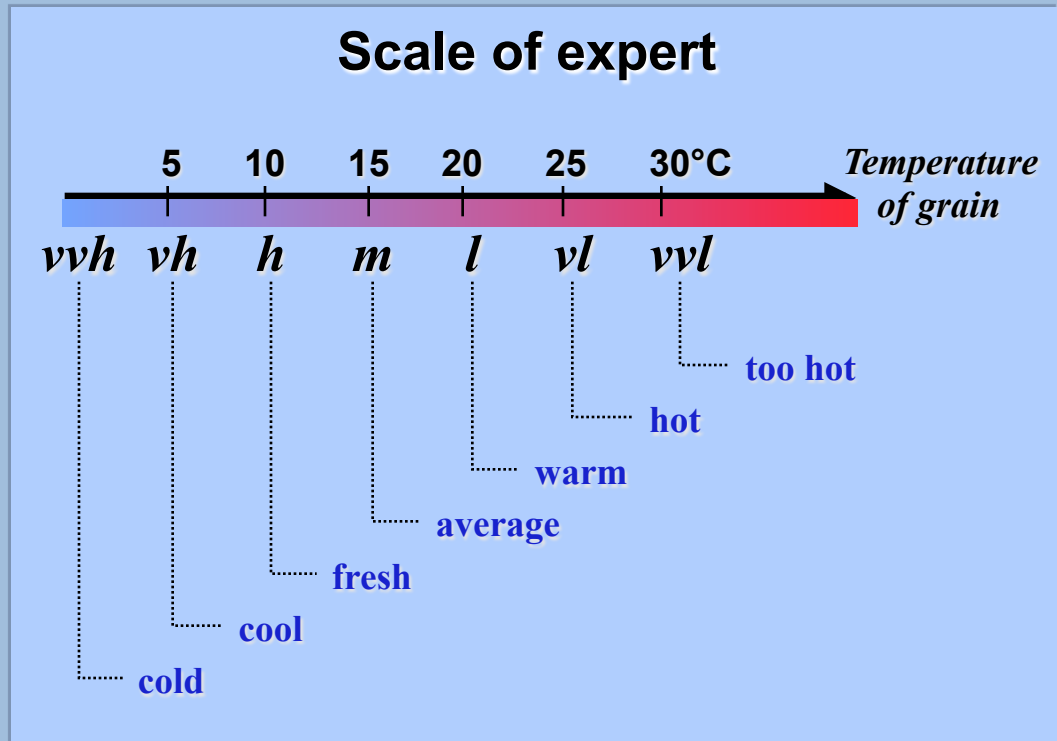
Amadou Ndiaye

INRA

France

Preventive strategy
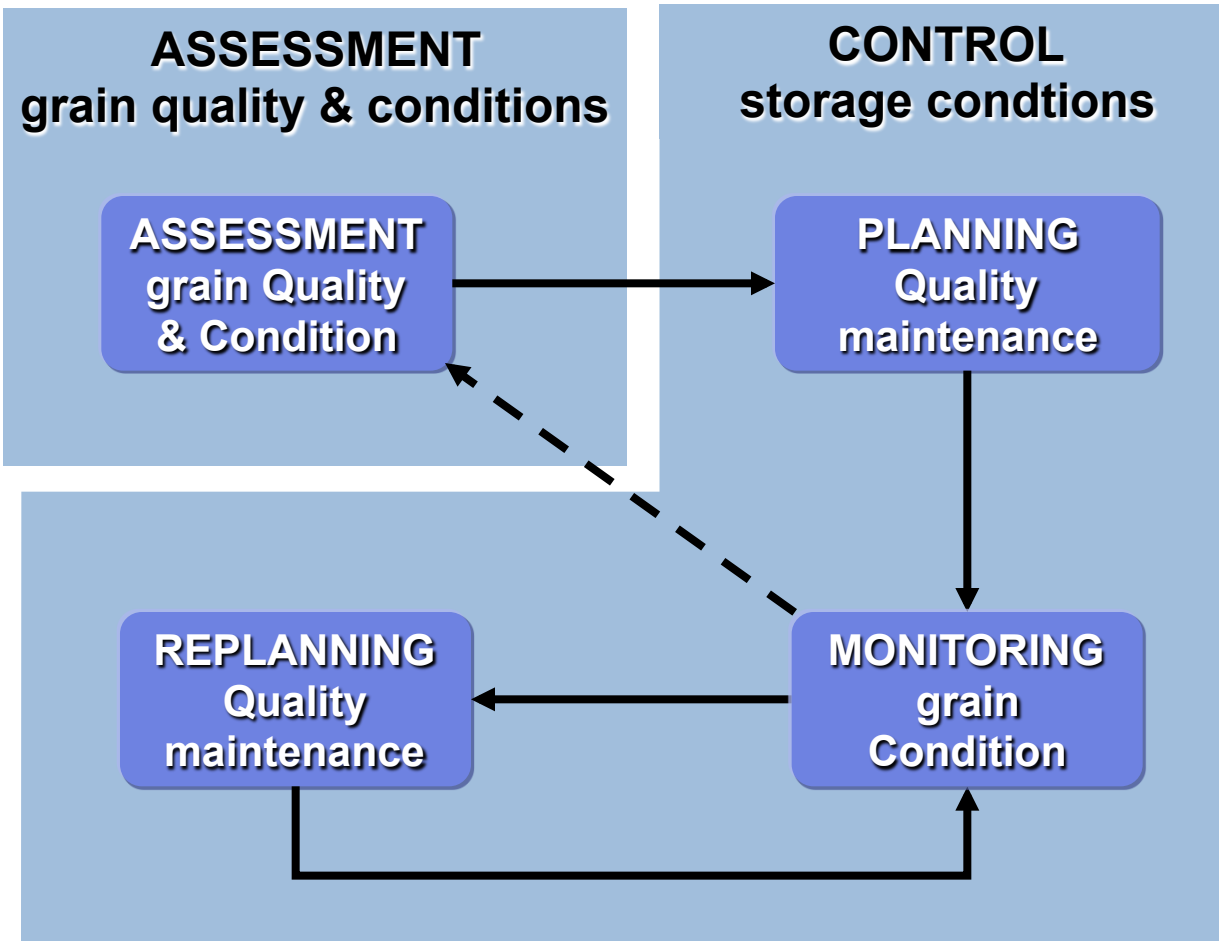
Assessment of Grain Quality
Grain Quality Space

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Scale of expert

5   10   15   20   25   30°C   *Temperature of grain*

vvh *vh* *h* *m* *l* *vl* *vvl*

too hot

hot

warm

average

fresh

cool

cold

- **7 elements symbolic space**
  {vvl, vl, l, m, h, vh, vvh}
- **Ordered space**
  vvl < vl < l < m < h < vh < vvh
- **2 basic functions *pred* and *suc***
  $pred(m) = h$, $pred(vvh) = vvh$
  $suc(m) = l$, $suc(vvl) = vvl$
  $pred(suc(m) = suc(pred(m) = m$
  $pred(pred(m)) = vh$, $suc(suc(m) = vl$
- **3 comparison operators**
  eq, gt, lt
- **4 composing operators**
  min, max, min-max, max-min
  $min(x,y)=x \Leftrightarrow x$ *lt* y
  $max(x,y)=x \Leftrightarrow x$ *gt* y
- ***Ad-hoc* operators**
  α, β ...

Assessment of Grain Quality
Human experts cognitive operations

Technological potentiel

Composite variables

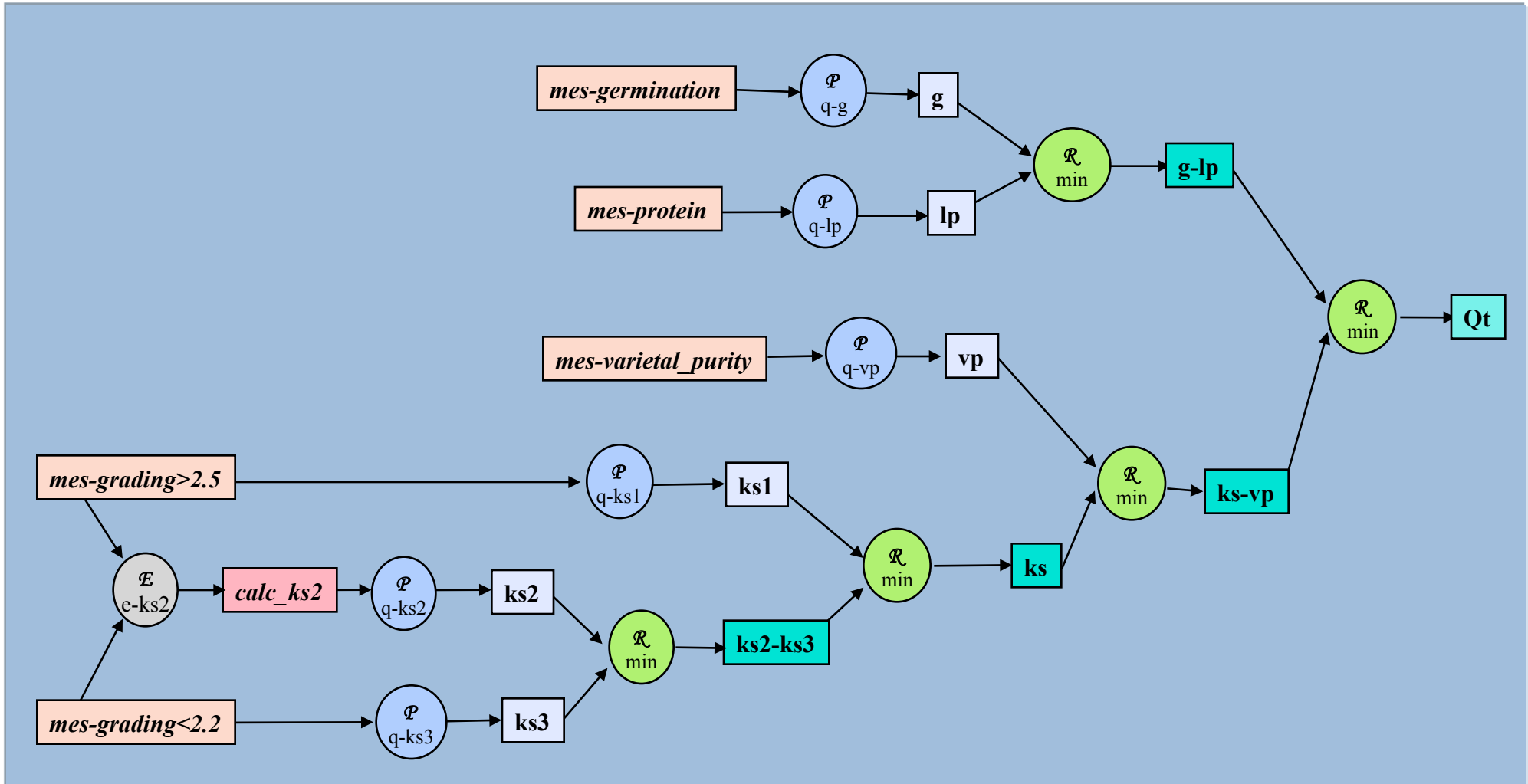| Germinative capacity | Protein content | Variety | Varietal Purity | Grading |
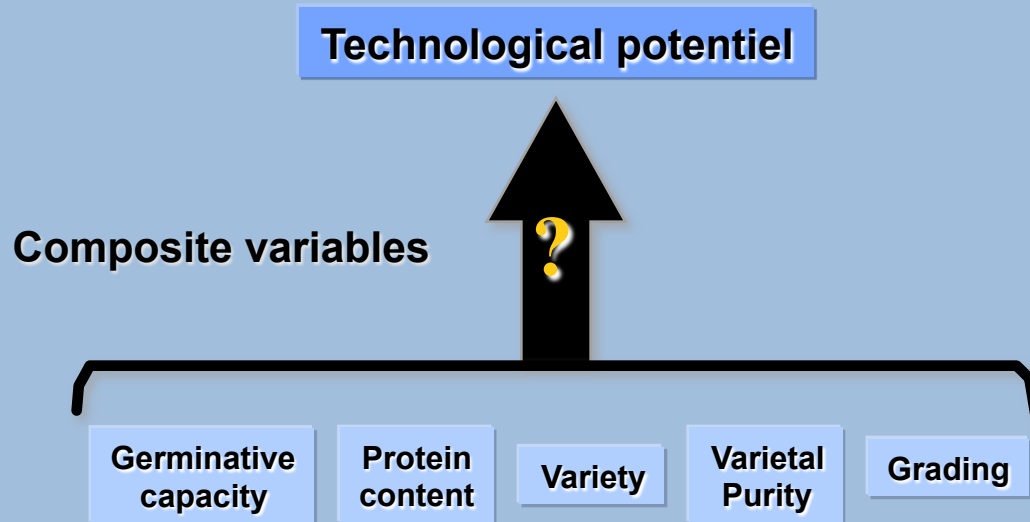
7 Abstracts operations

- **Projection ($\mathcal{P}_j$)**
  $\mathcal{P}_j : R \rightarrow Q$ or $V \rightarrow Q$
- **Reduction ($\mathcal{R}$)**
  $\mathcal{R} : Q \times Q \rightarrow Q$
- **Deduction ($\mathcal{D}$)**
  $\mathcal{D} : Q \times Q \rightarrow Q$ or $Q \rightarrow Q$
  or $Q \rightarrow V$ or $V \rightarrow V$
  or $V \times V \rightarrow R$
- **Induction (I)**
  $I : Q \rightarrow Q$
- **Prediction ($\mathcal{P}$)**
  $\mathcal{P} : R \rightarrow Q$ or $R \times R \rightarrow Q$
- **Critic (C)**
  $C : Q \rightarrow V$ or $Q \times Q \rightarrow V$
- **Equation ($\mathcal{E}$)**
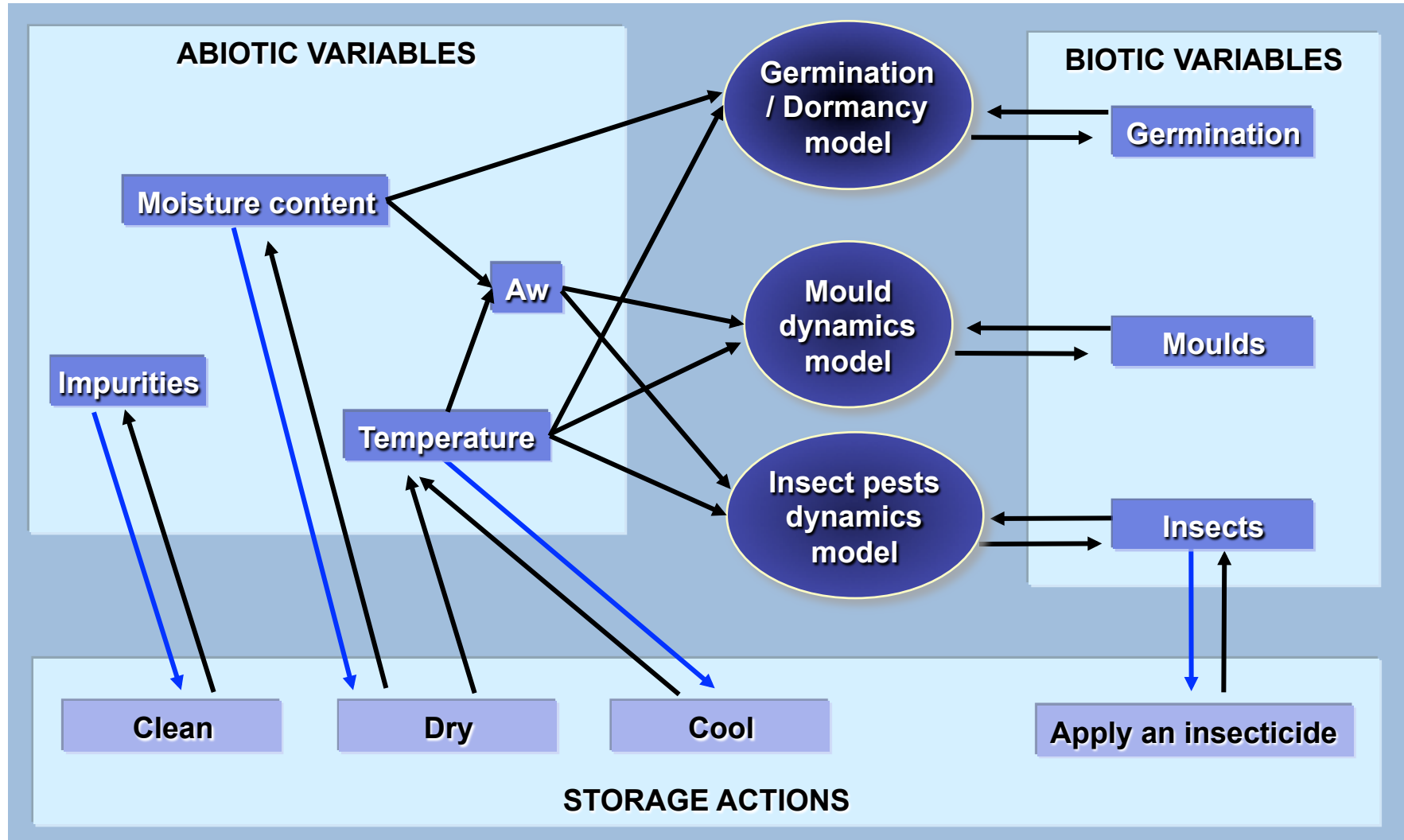 $\mathcal{E} : R^n \rightarrow R$ with $n > 0$

Assessment of Grain Quality
Technological potential
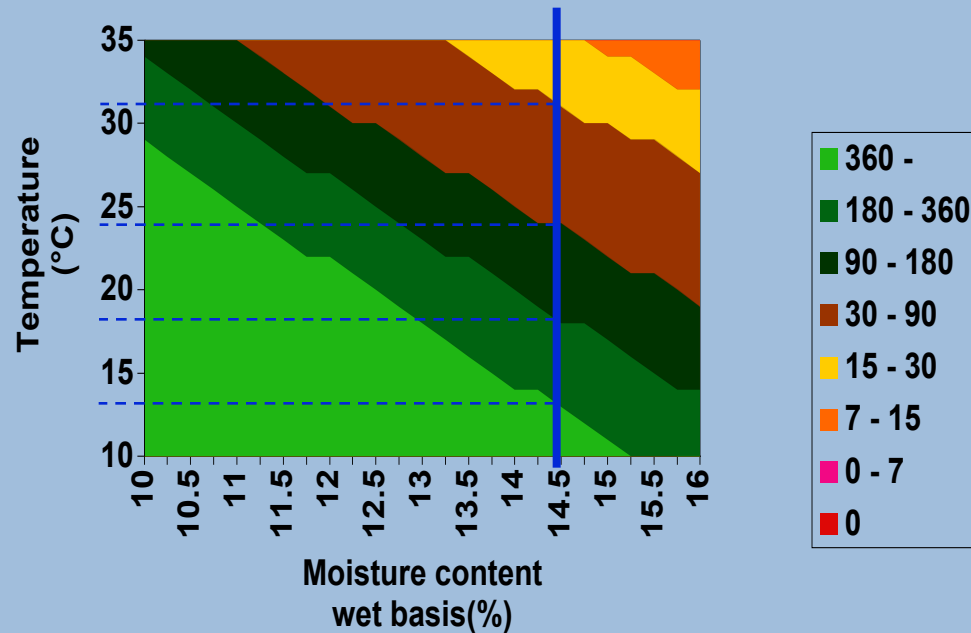
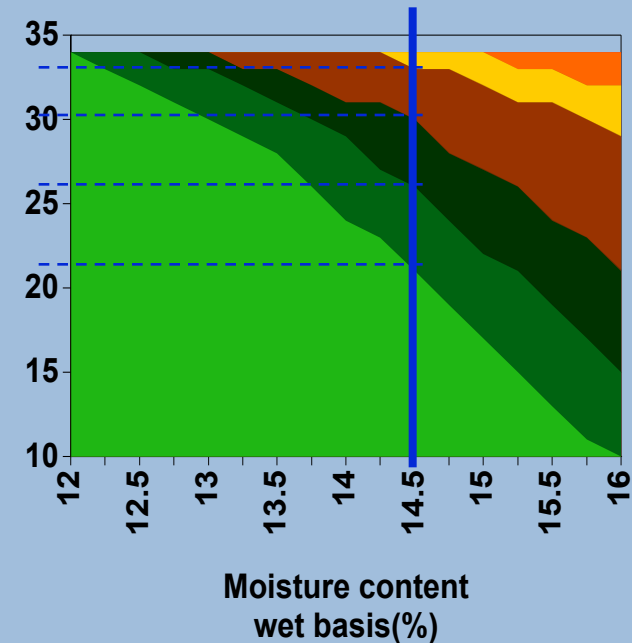# Control of storage condtions
Planning of quality maintenance

Control of storage condtions
Stability zone: Monitoring of grain condition

Germinative capacity decrease to 95%

Spoilage by moulds

Legend:
- 360 -
- 180 - 360
- 90 - 180
- 30 - 90
- 15 - 30
- 7 - 15
- 0 - 7
- 0

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Implementation
Flexible modular architecture
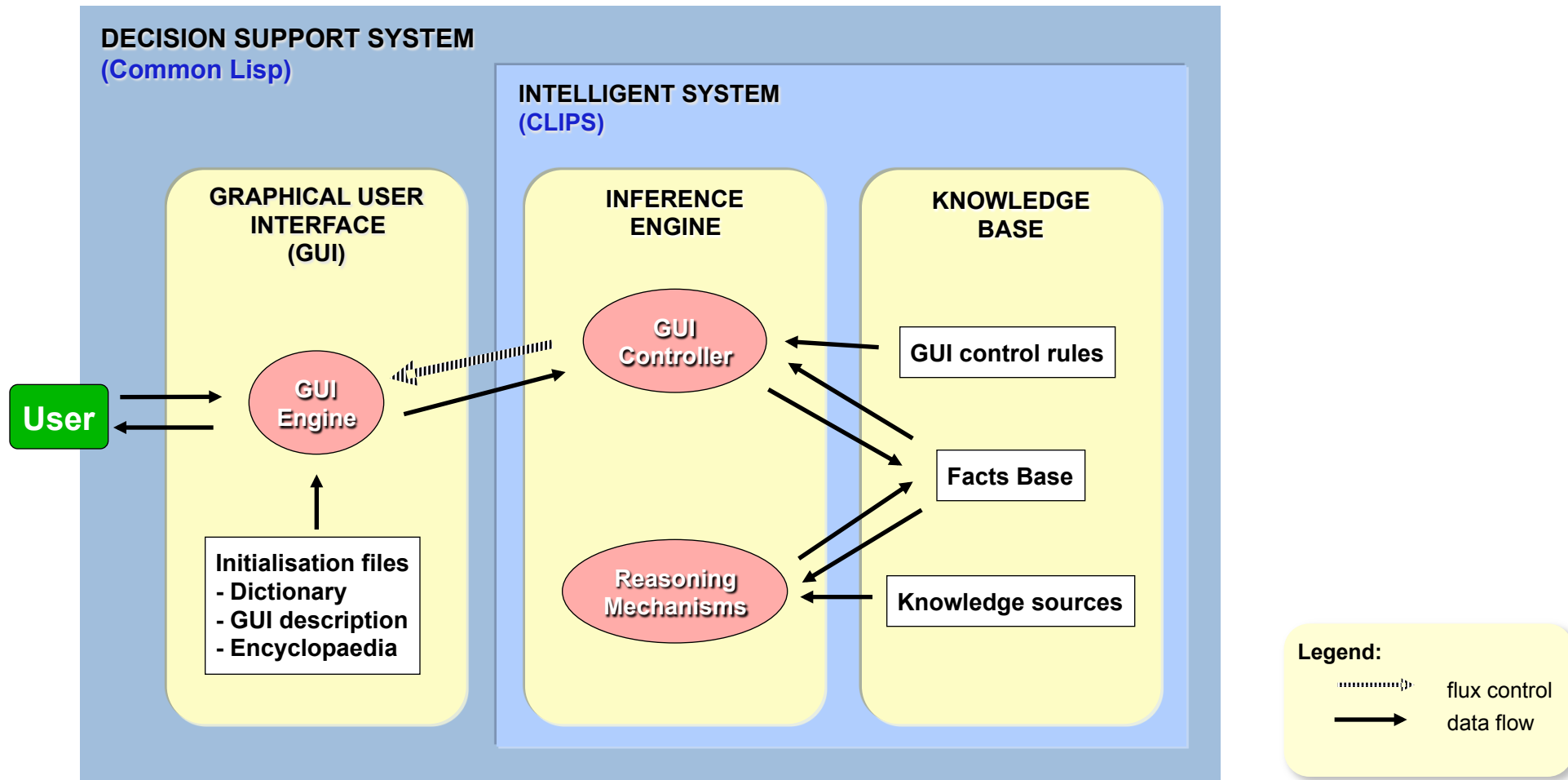
DECISION SUPPORT SYSTEM
(Common Lisp)

INTELLIGENT SYSTEM
(CLIPS)

GRAPHICAL USER INTERFACE (GUI)

INFERENCE ENGINE

KNOWLEDGE BASE

User

GUI Engine

GUI Controller

GUI control rules

Facts Base

Reasoning Mechanisms

Knowledge sources

Initialisation files
- Dictionary
- GUI description
- Encyclopaedia

Legend:

······⫸ flux control

→ data flow

Input of raw data

Assessment of malting barley quality and condition

ECC-Paris symposium

The optimal storage technical routes

INRA

Qualis

FILE   HELP-MENU

Results

5 DIFFERENT STORAGE TECHNICAL ROUTES HAVE BEEN PLANNED

Plan 1 . Store in Bin-1 and Cool with Refrigerator-1 to maintain the barley quality during 370 days
Plan 2 . Store in Bin-1 and Cool with Fan-1 to maintain the barley quality during 411 days

details   Bin-1 and Cool with Fan-2 to maintain the barley quality during 406 days

Plan 4 . Store in Bin-2 and Cool with Fan-1 to maintain the barley quality during 411 days
Plan 5 . Store in Bin-2 and Cool with Fan-2 to maintain the barley quality during 406 days

Ok

The detail of the PLAN 2

Qualis

FILE   HELP-MENU

Results

PLAN 2

2 storage oprations to carry out during 48 days to maintain the barley quality during 411 days

Initial grain condition:
    germinative capacity 80%, temperature 25°C, moisture content 14.50%, activity of water 0.73,
    level of impurities 2.00%, free living insects 0/kg, free dead insects 0/kg, insecticide none
The estimated safe storage periodes in the same grain condition are 69 days for the germinative capacity,
  26 days for the dormancy break, 43 days for the maximum germinative energy and 185 days for the moulds

1. Store grain in the vertical bin Bin-1
   Grain condition:
    germinative capacity 80%, temperature 25°C, moisture content 14.50%, activity of water 0.73,
    level of impurities 2.00%, free living insects 0/kg, free dead insects 0/kg, insecticide none
The estimated safe storage periodes in the same grain condition are 69 days for the germinative capacity,
  26 days for the dormancy break, 43 days for the maximum germinative energy and 185 days for the moulds

2. Cool grain using the fan Fan-1 in 3 steps to reach 10°C of temperature in 48 days for an estimated period of 228 days
   Step 1 to reach 22°C of temperature in 4 days for an estimated period of 180 days
        The estimated safe storage periodes in the same grain condition are 104 days for germinative capacity,
         31 days for dormancy break, 59 days for maximum germinative energy and 284 days for moulds
   Step 2 to reach 15°C of temperature in 18 days for an estimated period of 180 days
        The estimated safe storage periodes in the same grain condition are 257 days for germinative capacity,
         21 days for dormancy break, 104 days for maximum germinative energy and 690 days for moulds
   Step 3 to reach 10°C of temperature in 26 days for an estimated period of 180 days

   Grain condition:
    germinative capacity 96.99%, temperature 10°C, moisture content 14.50%, activity of water 0.70,
    level of impurities 2.00%, free living insects 0/kg, free dead insects 0/kg, insecticide none
The estimated safe storage periodes in the same grain condition are 460 days for the germinative capacity,
 0 days for the dormancy break, 138 days for the maximum germinative energy and 1309 days for the moulds

=> IT IS RECOMMANDED TO CONTROL THE PRESENCE OF INSECTS IN 411 DAYS

****

    THE DELAY NECESSARY FOR A SUFFICIENT DECREASING OF THE TEMPERATURE BETWEEN
    TWO COOLING AERATION STEPS IS NOT ACCOUNTED FOR IN THIS DEMO VERSION
****

Ok

ECC-

The detail of the PLAN 2

PLAN 2

2 storage oprations to carry out during 48 days to maintain the barley quality during 411 days

Initial grain condition: GermC 80%, T 25°C, mc 14.50%, Aw 0.73, Imp 2%, insect 0/kg

The estimated safe storage periodes in the same grain condition are

Germinative capacity 69d and Moulds 185d (DormB 26d, maxGermC 43d)

1. Store grain in the vertical bin Bin-1

Grain condition: GermC 80%, T 25°C, mc 14.50%, Aw 0.73, Imp 2%, insect 0/kg

The estimated safe storage periodes in the same grain condition are

Germinative capacity 69d and Moulds 185d (DormB 26d, maxGermC 43d)

The detail of the PLAN 2

2. Cool grain using the fan Fan-1 in 3 steps to reach 10°C of temperature in 48 days for an estimated period of 228 days

Step 1 to reach 22°C of temperature in 4 days for an estimated period of 180 days

    The estimated safe storage periodes in the same grain condition are

    Germative capacity 104d and Moulds 284d (DormB 31d, maxGermC 59d)

Step 2 to reach 15°C of temperature in 18 days for an estimated period of 180 days

    The estimated safe storage periodes in the same grain condition are

    Germinative capacity 257d and Moulds 690d (DormB 21d, maxGermC 104d)

Step 3 to reach 10°C of temperature in 26 days for an estimated period of 180 days

Grain condition: GermC 96.99%, T 10°C, mc 14.5%, Aw 0.7, Imp 2%, insect 0/kg

The estimated safe storage periodes in the same grain condition are

    Germinative capacity 460d and Moulds 1309d (DormB 0d, maxGermC 138d)

=> IT IS RECOMMANDED TO CONTROL THE PRESENCE OF INSECTS IN 411 DAYS

The delay necessary for a sufficient decreasing of the temperature between two cooling aeration steps is not accounted for in this demo version

Conclusions

- Representation of a heterogeneous complex system
- Mixed quantitative and qualitative reasoning
- Integration of mathematics models and expert knowledge
- Integration of time
- Implementation of a prototype on a PC computer: *QualiS©*
- Validation by the experts
- Validation in pilot scale experiments 10 tons (DK) & 20 tons (UK)

Prediction of the duration of cooling aeration and its effects to refine

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