Contribution to sustainable development (CDD):

This criteria synthetizes all qualitative criteria linked to the cropping system evaluation in the three dimensions: economic, social and environmental. The weights are those proposed by default in the tool and can be changed. Input criteria in italic have to be determined in a qualitative way, those in bold are also qualitative but can be determined with a satellite tree. The remaining ones can be determined in a quantitative way and transformed in qualitative value. All the aggregated criteria are qualitatively estimated.
Economic dimension

This branch evaluates the CS contribution to the economic dimension of sustainability. It takes into account priorities and concerns of farmers, society and sectors.

Profitability (MSN)

Semi-net margin, short term profitability for the farmer

\[ \text{MSN} = \left( \sum_i \left( \text{PB}_i + \text{SA}_i - \text{CO}_i - \text{CM}_i \right) \right) / n \]

- **PB**: Gross product (€/ha) = quantity harvested x selling price
- **SA**: Total subsidies received (€/ha)
- **CO**: Operational charges (€/ha) linked to seed, fertilizers and pesticides, fuel, temporary labour work, irrigation
- **CM**: Mechanization charges (€/ha) (material amortization and maintenance)
- **n**: Rotation length (years)

Economic independence (IND)

CS dependence on public subsidies

\[ \text{IND} = \left[ \sum_i \left( 1 - \left( \frac{\text{SA}_i}{\text{MSN}_i} \right) \right) \times 100 \right] / n \]

- **SA**: Total subsidies perceived (€/ha)
- **MSN**: Semi-net margin (see before)
- **n**: Rotation length (years)
- **i**: Year
**Economic efficiency (EFF)**

CS dependence on inputs. A high dependence implies a higher risk linked to the input market (ex: fertilizer price variability, ...)

\[
EFF = \left[ \sum_{i} \left( \frac{PB_i}{(CO_i + CM_i)} \right) \times 100 \right] / n
\]

- **PB** : Gross product (€/ha) = quantity harvested x selling price
- **CO** : Operational charges (€/ha) linked to seed, fertilizers and pesticides, fuel, temporary labour work, irrigation
- **CM** : mechanization charges (€/ha) material amortization and maintenance
- **n** : rotation length (years)

**Specific material needs (MAT)**

The new CS may require new specific material which can be expensive compared to the farm investment capacity.

**Qualitative value**

Which material will the farmer need for the new CS (crop, intercrop, tillage, ...) ? Does he already have it on his farm ? If no, does this new material cost a lot compared to the farm investment capacity ?

- **Low** : no specific material to buy for the new CS
- **Medium** : some specific material needed but not too expensive and use on a large surface
- **High** : specific material to buy, high price and small surface concerned
Control of soil structure (MESS)

A soil regeneration is long and expensive, that’s why control of the structure is necessary to keep a long term productivity of the plot.

Control of acido-basic balance (MSAB)

A bad control of acido-basic balance of the soil decreases soil fertility.
Control of potassium and phosphorus fertility

A bad control of the potassium and phosphorus balance of the soil decreases soil fertility

Satellite tree:

- Initial P/K fertility → Soil analysis
- Buffering capacity
  - Sandy, sand loam: low
  - Light loam, medium loam: medium
  - Clay, loamy clay, loamy-sandy clay: high
- Balance and recycling
  - Mean balance over a year
  - Recycling by harvest stubbles → Intern recycling (kg/ha/an)
  - Year balance (kg/ha/an)

Control of insect pests and diseases (MMR)

The control of insect pests and diseases to a low population can preserve production capacity of the plot.

Satellite tree:

- Family crop diversity → Simpson indice
  - $DFC = 1 / \sum (p_i^2)$
- Tillage effect
  - Direct sowing: Very low
  - Minimum tillage: Low to medium
  - Occasional ploughing: Medium to high
  - Regular ploughing: Very high
- Effet of control methods → See tab below
Control of weeds (MADV)

To keep the seed stock at a low level can avoid mid and long term risks and preserve production capacity of the plot.

Satellite tree:

Control of weeds

Effect of sowing period diversity

- Number of different periods (early autumn/moderately early autumn/late winter/early spring/late spring)

- Presence / absence

- Effect of control methods

See tab 3

Technological and esthetic quality (QTE)

Risk of failing to reach the quality required by the sector

\[ QTE = \frac{\sum Q_i}{n} \]

- \( n \): rotation length (years)
- \( Q_i \): quality of the crop
  - Quality required reached \( \Rightarrow Q_i = 2 \)
  - Low quality but the crop can be sell (for an other market outlet, a lower price, ...) \( \Rightarrow Q_i = 1 \)
  - Low quality and no possibility to sell \( \Rightarrow Q_i = 0 \)

Rq: consider both crops for the assessment of an intercrop
Sanitary quality (QS)

Linked to possible mycotoxin contaminations.

\[ \text{QSP} = \left( \sum_i \text{IS}_i \right) / \text{NC} \]

\( \text{IS}_i \): contamination risk for sensitive crops (See tab 1)
\( \text{NC} \): crop number in the CS

\( \text{RQ} \): \( \text{IS}_i \) depending on the preceding crop, the presence or not of ploughing practices and of the susceptibility of the crop to fusariose.

Contribution to new sector emergence (CENF)

The crop system participates in economic diversification of the region.

Qualitative value

*Is the new crop already harvested in the region?*
*Would it be easy to find an outlet for this new crop if it does not already exist?*

Low: this crop sector already exists
Medium: this crop sector does not exist but an outlet can easily be found
High: this sector does not exist and it would be difficult to find an outlet
Social dimension

This branch evaluates the CS contribution to the social dimension of sustainability through its compatibility to social expectations of farmers and society.

### Work overload (SDT)

#### Work overload during peak periods

### Qualitative value

*When is this new crop sowed? harvested? Is it at the same time as the other crops?*

*Does it require a lot of tillage and treatments? Does it need to be sort out after the harvest (intercrop)?*

**Low**: sowing/harvest at other dates than the crops already implemented

**High**: increase work during peak periods

### Physical difficulty (DIFF)

#### Penibility of the CS techniques

### Qualitative value

*Does the new crop imply difficult or tiring gestures? Is it detrimental to the worker health?*

We suppose this criteria always at a **medium** level: it is not discriminating for our CSs.
Health risk for the user (TOX)

\[ \text{TOX} = \frac{\sum P_{P_i}}{n} \]

\( P_{P_i} \): Number of passages with at least one pesticide of the TNX list.
\( n \): rotation length (years)

RQ: TNX is a classification of toxic pesticides in France. This criteria calculation has to be adapted to each country. If protection clothes are not used, \( \text{TOX} = \text{TOX} +1 \).

Cropping system complexity (CIC)

Implementation ease of the CS.

\[ \text{CIC} = \frac{\sum K_i}{n} \]

\( K_i \): complexity associated to each year of the rotation
- Cereals (wheat, barley, oat, ...) / rainfed summer crops (maize, sorghum, sunflower, ...) => \( K_i=0 \)
- Irrigated summer crops, pea, lupin, rapeseed, lentils, ... => \( K_i=1 \)
- Tobacco, onions, carrots, intercrops, ... => \( K_i=2 \)

\( n \): rotation length (years)

Time to acquire technical and economic knowledge (TVTE)

A long and diversified rotation is more complicated for the farmer and implies more time to acquire technical and economic information.

It is estimated through number of different crops in the rotation

RQ: This assessment method do not consider amount of information available for a crop (ex: wheat vs marginal crop).
**Contribution to employment (EMP)**

Contribution of the CS to social insertion and local development through creating and maintaining employment.

\[ EMP = \frac{\sum_i NH_i}{n} \]

- **NH_i**: number of hours worked/ha for year i
- **n**: rotation length (years)

**Raw material supply (FMP)**

Contribution of the CS to satisfy agricultural production required by society

\[ FMP = \frac{\sum_i (IRA_i / IRI_i) \times 100}{n} \]

- **IRA_i**: yield expected or effective for the crop i
- **IRI_i**: potential yield reached in an intensive management for the same crop i
- **n**: rotation length (years)
Environmental dimension

This branch evaluates the CS contribution to the environmental dimension of sustainability through its ability to preserve resources, environment quality and biodiversity.

Control of pesticide losses into surface waters (MPES)

The crop system can have an impact on the quality of surface waters through pesticides.

\[
MPES = \frac{\left( \sum_{i} I_{PHY}^{SA Eaux superficielles i} \right)}{n}
\]

- **MPES**: emission risk in surface waters for the active substance i (INDIGO indicator)
- **n**: rotation length (years)

\[Rq : INDIGO \ indicator \ used \ but \ any \ indicator \ for \ pesticide \ emission \ risk \ can \ be \ used.\]
Control of pesticide losses into ground waters (MPES)

The crop system can pollute through losses of pesticides into ground waters

\[
MPEP = \left( \sum_i I \cdot PHY_{SA \text{ Eaux profondes}_i} \right) / n
\]

I-PHY : emission risk in ground waters for the active substance i (INDIGO indicator)

n : rotation length (years)

Rq : INDIGO indicator used but any indicator for pesticide emission risk can be used.

Control of NO3 losses (MNO3)

Control of NO3 emissions into waters. A high nitrate concentration is detrimental to aquatic life and to clear water for human use.

\[
MPNO3 = \left( \sum_i I_{NO3_i} \right) / n
\]

INO3i : nitrate leaching indicator for year i (INDIGO indicator)

n : rotation length (years)

Rq : INDIGO indicator used but any indicator for nitrate leaching risk can be used.
Control of P losses (MPPH)

Risk of P losses from the soil into waters (responsible for eutrophisation).

Control of P losses

Satellite tree:

- P content of the soil
- Control of erosion
- Amendment management

Incorporation method:

- Incorporation during sowing or no input: Low
- Incorporation just before sowing: Medium
- Incorporation more than 3 months before sowing or no incorporation: High

Mean P input quantity → Kg P2O5/ha/an

Control of NH3 emissions (MNH3)

Risks of NH3 losses by volatilization

\[
MNH3 = \frac{\sum_{i} INH3_i}{n}
\]

\( INH3_i \): NH3 loss indicator for year i (INDIGO indicator)
\( n \): rotation length (years)

Rq: INDIGO indicator used but any indicator for NH3 losses can be used.
Control of N2O emissions (MN2O)

Risk of N2O losses in the atmosphere

\[ \text{MN2O} = \left[ \sum \text{IN2Oi} \right] / n \]

\text{IN2Oi} : N2O emission indicator for year i (INDIGO indicator)
\text{n} : rotation length (years)

Rq : INDIGO indicator used but any indicator for N2O emissions can be used.

Control of pesticide emissions (MPA)

Atmosphere pollution risks through pesticide losses.

\[ \text{MPA} = \left( \sum \text{I-PHY}_{\text{SA, air, i}} \right) / n \]

\text{I-PHYi} : emission risk of pesticides into the air for year i (INDIGO method)
\text{n} : rotation length (years)

Rq : INDIGO indicator used but any indicator for pesticide emission risk can be used.
Control of soil erosion (MERO)

Risk of soil quality degradation

Satellite tree:

- Control of soil erosion
  - Environment sensitivity
    - Control of soil structure
      - See corresponding criteria
        - Direct sowing: Very low
        - Minimum tillage: Low to medium
        - Occasional ploughing: Medium to high
        - Regular ploughing: Very high
      - Lack of cover during risk periods
        - %
  - Effect of CS
    - Tillage effect
      - 10
  - 45

Control of organic matter content (MSO)

CS impact on the soil organic matter. A good balance will provide good agro and environmental services.

\[
MSO = \sum_i (IMO_i) / n
\]

IMO_i: organic matter indicator for year i (INDIGO indicator)

n: rotation length (years)

Rq: INDIGO indicator is proposed but any indicator for organic matter can be used.

We used SIMEOS tool to have a better detail for legumes
Control of toxic element accumulation (MAET)

Long term control of accumulation of toxic elements (copper, zinc, lead, cadmium)

Qualitative value

*Does the region present a particular risk for toxic elements accumulation? Could the chemical inputs used be a potential source of pollution in toxic elements?*

We suppose this criteria always at a **high** level: it is not discriminating for our CSs

Water use during critical periods (IRRC)

Crop water needs during critical periods. These periods correspond usually to summer or low water level periods.

\[
\text{IRRC} = \frac{\sum I_{pc_i}}{n}
\]

\( I_{pc_i} \): water quantity for the irrigation of a crop i during critical period
\( n \): rotation length (years)

Dependence on water resources (DPEAU)

High dependence on water resources is not sustainable

Satellite tree:

- **Crop water needs**
- **Dependence on water resources**
- **Ressource autonomy**

\[
\text{DMEAU} = \frac{\sum \text{ETM}_i}{n}
\]

\( \text{ETM}_i \): Sum of maximal evapo-transpiration of crop i (from sowing to harvest)

\[
\text{AUTEA} = \frac{\sum (I_i/DMEAU)}{n}
\]

\( I_i \): Irrigation water quantity for a crop year i (mm/ha)
Energy consumption (CENB)

Energy consumption coming from non-renewable resources.

\[
CEN = \frac{(\sum_i I_{EN,i})}{n}
\]

\( I_{EN,i} \) : energy consumption indicator for crop \( i \) (INDIGO indicator)
\( n \) : number of culture cycles in the rotation

Energy efficiency (EEN)

Energetic performance of a CS considering consumption and production.

\[
EEN = \left\{ \frac{\sum_i (E_{Pi} / E_{Ti})}{n} \right\}
\]

\( E_{Pi} \) : produced energy on year \( i \)
\( E_{Ti} \) : consumed energy on year \( i \)
\( n \) : rotation length (years)

Phosphorus pressure (PSPH)

CS pressure on non-renewable phosphorus resources (fertilizer use).

\[
PSPH = \frac{(\sum_i QPNR_i)}{n}
\]

\( QPNR_i \) : Non-renewable phosphorus input (kg P2O5/year)
\( n \) : rotation length (years)
Soil macrofauna conservation (CMS)

Impact of the CS on abundance and diversity of soil macrofauna

Satellite tree:
- Tillage effect
- Effect of organic matter input
- Insecticide TFI

<table>
<thead>
<tr>
<th>Tillage effect</th>
<th>Direct sowing</th>
<th>Very low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum tillage</td>
<td>Low to medium</td>
<td></td>
</tr>
<tr>
<td>Occasional ploughing</td>
<td>Medium to high</td>
<td></td>
</tr>
<tr>
<td>Regular ploughing</td>
<td>Very high</td>
<td></td>
</tr>
</tbody>
</table>

See corresponding criteria

Mean TFI for insecticides on the rotation

Flying insect conservation (CIV)

Impact of the CS on abundance and diversity of flying insects

Satellite tree:
- Effect of family crop diversity
- Insecticide TFI

Simpson indice
\[ DFC = 1/ \sum (p_i^2) \]

Mean TFI for insecticides on the rotation

Floristic abundance (ABOF)

Biodiversity within the field concerning non cultivated plants

It is estimated as the reverse of weed control

RQ: This assessment method does not consider cultivated plant diversity, as intercrops.
Floristic diversity (DIVF)

Impact of the CS on plant diversity of the field

Satellite tree:

Floristic diversity

- Effect of sowing period
- Use of broad spectrum insecticides
- Field border management

Number of different periods (early autumn/moderately early autumn/late winter/early spring/late spring)
TFI only with broad spectrum herbicides

Same management as plot: Low
Different and extensive management: Medium
Sowing of adapted species: High

Micro-organism conservation (CMO)

Impact of the CS on abundance and diversity of soil micro-organisms

Satellite tree:

Micro-organism conservation

- Effect of crop family diversity
- Effect of organic matter inputs
- Total TFI

Simpson indice
\[ DFC = \frac{1}{[\sum (p_i^2)]} \]
See corresponding criteria
Mean on the rotation
<table>
<thead>
<tr>
<th>Preceding crop</th>
<th>Cultural practices</th>
<th>Susceptibility to fusariose</th>
<th>Risk level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ploughing</td>
<td>Low susceptibility</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Moderate susceptibility</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Susceptible</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Rapeseed, peas, faba beans, sunflower, ...</td>
<td>No ploughing</td>
<td>Low susceptibility</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Moderate susceptibility</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Susceptibility</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Straw cereals</td>
<td>Ploughing</td>
<td>Low susceptibility</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Moderate susceptibility</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Susceptibility</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No ploughing</td>
<td>Low susceptibility</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Moderate susceptibility</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Susceptibility</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Maize, sorghum</td>
<td>Ploughing</td>
<td>Low susceptibility</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Moderate susceptibility</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Susceptibility</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No ploughing</td>
<td>Low susceptibility</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Moderate susceptibility</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Susceptibility</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

If the crop is a legume then IS = 0 as there’s no fusariose problem on legumes.
Tab 2: Effect of acidifying practices [Control of soil acido-basic balance]

<table>
<thead>
<tr>
<th>Use of acidifying fertilizers</th>
<th>UEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Low use</td>
<td>1</td>
</tr>
<tr>
<td>Moderate use</td>
<td>2</td>
</tr>
<tr>
<td>Important use</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N balance</th>
<th>BA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative (&lt; 0 kg N/ha/an)</td>
<td>0</td>
</tr>
<tr>
<td>In balance (between 0 and 30 kg N/ha/an)</td>
<td>1</td>
</tr>
<tr>
<td>Positive balance (between 30 and 60 kg N/ha/an)</td>
<td>2</td>
</tr>
<tr>
<td>Very positive balance (&gt; 60 kg N/ha/an)</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Legume proportion in the rotation</th>
<th>PLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>0&lt;30%</td>
<td>1</td>
</tr>
<tr>
<td>&gt; 30%</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Harvest stubble exportation</th>
<th>EXC</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Occasionnal</td>
<td>1</td>
</tr>
<tr>
<td>Frequent</td>
<td>2</td>
</tr>
</tbody>
</table>

\[ \text{EPA} = \text{UEA} + \text{BA} + \text{PLR} + \text{EXC} \]

See Threshold values to determine classes
Tab 3: Effect of control methods for weeds [Weed control]

<table>
<thead>
<tr>
<th>Physical control index (PCI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between crop period: superficial mechanical interventions (mean)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Crop: mechanical weeding</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemical control index (CCI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between crop period</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Crop</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control by cover index (CoCi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between crop period</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Crop</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

⇒ Effect for crop i = PCI + CCI + CoCi
⇒ Total effect for the rotation = Σi (PCI+CCI + CoCi) / n

See Threshold values to determine classes
Tab 4: Effect of control methods [Control of insect pests and diseases]

<table>
<thead>
<tr>
<th>Genetic control index (GCI)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No or low resistance to parasites</td>
<td>0</td>
</tr>
<tr>
<td>Medium resistance to parasites</td>
<td>1</td>
</tr>
<tr>
<td>Resistance to parasites</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biological control index (BCi)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Use of biological control product(s)</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemical control index (CCI)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TFI without herbicides = 0</td>
<td>0</td>
</tr>
<tr>
<td>Integrated control strategy</td>
<td>1</td>
</tr>
<tr>
<td>Conventionnal control strategy</td>
<td>2</td>
</tr>
</tbody>
</table>

\[\text{Effect for crop } i = \text{ GCI} + \text{ BCi} + \text{ CCI}\]

\[\text{Total effect for the rotation} = \frac{\sum (\text{GCI}+\text{BCi}+\text{CCI})}{n}\]

See Threshold values to determine classes.