# ENERGY BALANCE OF DIFFERENT INTENSIVE FORAGE CROPPING SYSTEMS IN NORTHERN ITALY

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**ABSTRACT**

Five forage crop rotations at two intensification levels have been compared using energy analysis, to have an integrated view on the systems under study. Inputs required by the five rotations ranged from 33 to 72 GJ•ha$^{-1}$•yr$^{-1}$. Outputs from cropping systems ranged from 41 to 153 GJ•ha$^{-1}$•yr$^{-1}$ and output/input ratios from 1,25 to 2,13. The most efficient rotations in terms of net energy production efficiency have been characterised by reduced length and presence of maize and catch-crops. Low intensification level has caused higher efficiency in three rotations.

**KEYWORDS**

Energy analysis, cropping systems, rotations, forage crops

**INTRODUCTION**

Dairy cattle feeding based on fodder crops has been changed in the Po Valley (northern Italy) during the last twenty-five years. The one-year rotation of Italian ryegrass (*Lolium multiflorum Lam.*) followed, in the same year, by silage maize (*Zea mays L.*) has replaced the traditional rotated meadow to obtain higher production, lower costs and a better organization of work. Such a system is largely developed in sandy-loam soils, that are easy to be ploughed and in districts with large availability of water for irrigation. Products are transformed into milk for human consumption or soft cheese. Such an intensive agriculture is possible thanks to the great capital input and the large availability of production factors coming from outside the farm. Energy analyses of real or experimental cropping systems have been carried out in many countries and in Italy too (Bonari et al., 1992; Giardini et. al., 1983; Pellizzi, 1992; Toderi et al., 1981), but no research has been made on forage crop systems.

For the mentioned reasons, our Institute started in 1985 a comparison between five forage cropping systems, at different degrees of intensification, with or without meadow and catch-crop. Milk feed units, dry matter yield and forage quality results have been measured over a 6-year period (Onofrii et al., 1993). In this work, an input-output energy analysis is carried out on the systems under comparison.

**MATERIALS AND METHODS**

The studies were carried out at Lodi, northern Italy. Rotation systems were: i) a 1-yr rotation in continuous monoculture of Italian ryegrass + silage maize (R1); ii) a 3-yr rotation of Italian ryegrass + silage maize, silage barley (*Hordeum vulgare L.*) + silage maize, grain maize (*Zea mays L.*) (R3); iii) a 6-yr rotation of Italian ryegrass + silage maize (3 yr) and rotated meadow (3 yr) of white clover (*Trifolium repens L.*) and tall fescue (*Festuca arundinacea Schreb.*) (R6); iv) a monoculture of permanent meadow with white clover, tall fescue and cocksfoot (*Dactilys glomerata L.*) (PM); v) grain maize in continuous monoculture (MM).

Each rotation underwent two crop management practices (inputs): medium - high (H) and medium - low (L), involving level of nutrients, weed control and soil tillage methods. The experimental design was a strip-split-plot. Input levels were assigned to main plots, 12 x 60 m, in three randomized complete blocks. Inputs have been registered for each crop in each rotation and for each intensification level.

Inputs and outputs have been multiplied by their respective energy contents (Bonari et al., 1992; Jarach, 1985; Pimentel & Pimentel, 1979). The output energy content of the pruduced forage has been estimated as net energy for milk cows.

Each plot belonging to rotational cropping systems has carried out a complete cycle during the 6 year period. Input and output means and output/input ratio have been calculated for each rotation and expressed in GJ•ha$^{-1}$•yr$^{-1}$.

**RESULTS AND DISCUSSION**

Inputs and outputs for each cropping system are shown in Table 1. At low intensification level, inputs range from 33 (PM) to 59 GJ•ha$^{-1}$•yr$^{-1}$ (R1). The lack of meadow in R1 and R3 causes higher values of inputs (above 50). At high intensification level, there is an appreciable increase of energy inputs, the mean values ranging from 38 (PM) to 72 (R1) GJ•ha$^{-1}$•yr$^{-1}$. It can be noted that, at both low and high intensification levels, energy inputs are lower in maize monoculture (MM) than in the 6-year rotation including the meadows (R6). Differences among mean values of net energy outputs from each cropping system are very high, ranging from 51 and 41 GJ•ha$^{-1}$•yr$^{-1}$ (for permanent meadow, at H and L intensification levels, respectively) to 153 and 142 (for R1). Therefore, energy output from R1 is thrice that from PM. For maize monoculture, only grain has been transformed into net energy: this explains the low values for outputs. Mean output is lower for the rotations including the meadow (R6 and PM), relative to the rotations without meadow (R1 and R3).

Output/input ratios (or *net energy production efficiencies*) are shown in Table 2. At high intensification level, R1 and R3 are the most efficient cropping systems, followed by R6 and MM, the less efficient being PM. At low intensification level, each rotation efficiency is significantly different from the other, according to the following rank: (R1 > R3 > R6 > MM > PM).

Results of the comparison between the two intensification levels within the same rotation (Table 2) show that R1, R3 and R6 are more efficient when the inputs are reduced, out/in ratio being higher under low than high intensification level.

Under the given pedological, climatic and agricultural conditions, the most efficient rotations have shown to be: i) short; ii) including maize; iii) including catch crops (e.g., *Italian ryegrass-silage maize or silage barley*).

Limiting factors to crop productivity (water, light and nitrogen) are better exploited by more efficient rotations. Maize (C4 species) has a more efficient light use and therefore requires and uses more water and nutrients. Mixed cropping systems (a main crop and a catch crop cultivated in succession within the year: R1, R3 and R6) allow a better exploitation of water and nutrients by covering the soil for a long period. Soil covering is very high also for the permanent meadow, which however has a low yield potential "*per se*".

The improvement of efficiency of R1, R3 and R6 rotations when adopting lower intensification levels suggests the opportunity of reducing inputs to these cropping systems, to limit consumption of not renewable resources and environmental pollution by intensive agriculture.

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**Table 1**
Energy inputs and outputs in five rotations at two intensification levels (H = higher; L = lower)

| | Rotation | Input | | Output | |
|---|---|---|---|---|---|
| | | H | L | H | L |
| Inputs and outputs ($GJ.ha^{-1}.yr^{-1}$) | R1 | 72 | 59 | 153 | 142 |
| | R3 | 63 | 52 | 130 | 114 |
| | R6 | 54 | 46 | 106 | 96 |
| | PM | 38 | 33 | 51 | 41 |
| | MM | 45 | 38 | 85 | 75 |

**Table 2**
Output/input ratios in five rotations at two intensification levels

| | Rotation | High[a] | Low[a] | Significance[b] |
|---|---|---|---|---|
| Output/input ratio | R1 | "2,13 a" | "2,42 a" | ** |
| | R3 | "2,08 a" | "2,19 b" | ** |
| | R6 | "1,95 b" | "2,11 c" | ** |
| | PM | "1,35 c" | "1,25 d" | n.s. |
| | MM | "1,88 b" | "1,99 e" | n.s. |

"a Means followed by the same letter are not different at P<0,05 (Duncan's test)"
"b ** Difference betwen intensifiction levels significant at P<0,01"