Deliverable 3.3: Report on modelling greenhouse gas emission including adoption behaviour of farmers regarding mitigation strategies and interfaces to the MIND STEP model toolbox

The main research objectives of this report were to identify technology and management measures to reduce GHG emissions from dairy farms in the Netherlands. Insights in farm level abatement costs and heterogeneity between individual farms or groups of farms is important information to understand the acceptance of GHG mitigation options and adoption behaviour of farmers and to develop more efficient GHG emission reduction policies. To achieve this, the bio-economic farm model FarmDyn (Britz et al., 2016) was applied to realistically analyse mitigation strategies to climate change for dairy farms in the Netherlands. FarmDyn was developed in such a way that it could be linked to the individual farm-level financial-economic and technical data from the Dutch Farm Accountancy Data Network (FADN). The FarmDyn data from Dutch FADN was enhanced with biophysical data from different sources. A literature review of generally available mitigation measures was used to identify options that could be included in the GHG accounting system of FarmDyn and combine them into an inventory of options. To take farmers' attitude, subjective norm, and perceived behaviour into account, a survey among Dutch dairy farmers was conducted. The results were used to create plausible scenarios regarding model farmers' behaviour regarding adoption of new technologies.

- What are the most relevant more short to medium term GHG mitigation options for Dutch dairy farmers?

The reduction potential of feed additives is estimated to be 32-48 g CO_2e/kg milk. This is a significant reduction and therefore additives can play a big role in reducing the methane emissions of dairy farming. In addition, replacing common concentrates with concentrates which reduce the emission of methane from enteric fermentation (EF) can add to more methane emission reduction. An important condition is that the production level does not change. The reduction potential of concentrates with low EF factor is estimated to be about 3 g CO_2e/kg milk. Through better animal management it is possible to increase the number of lactation periods per cow which leads to less GHG emissions through less young stock. Increased number of lactation periods per cow can lower the GHG emission with 10-20 g CO_2e/kg milk per extra year of life. Regarding upstream emissions from the use of N from mineral fertilizer, the enhancement of the fertilizer efficiency (less N from mineral fertilizer with equal crop yields) gives a possible emission reduction of 31 g CO_2e/kg milk. Using less fertilizer ensures less

CO2 emission by the production and application. Increased share of permanent grassland can increase carbon.

- What GHG mitigation measures are preferred by farmers

Comparing the inventory of options with the preferences indicated by farmers in the survey showed that inclusion of leguminous plants in the grassland management options and thus in the animal feed ration, production of renewable energy on farms, increase in feed efficiency and decrease artificial N-fertilizer were preferred options. They appeared differently depending on farm structure (e.g., number of livestock units per ha) and farmers' characteristics (e.g., age and education level).

- What are farm and farmers' characteristics that can explain adoption of GHG mitigation measures

This survey study explored the adoption behaviour of Dutch dairy farmers for climate change mitigation measures using a self-regulated stage model of behavioural change. The empirical analysis assessed the statistical associations of a rich set of socio-psychological and socio-demographical factors with Dutch dairy farmers' adoption of climate change mitigation measures. Our regression results show that negative emotion related to taking no climate mitigation measures, as well as action planning and coping planning are significantly and positively associated with the likelihood that farmers being in later stages, in which they have already adopted climate mitigation measures. Furthermore, farmers below and up to 50 years old with basic agricultural education and farms with high livestock density are found to be significantly and positively associated with later stages in the self-regulated stage model.

- What are the abatement costs of the selected GHG mitigation options for different groups of dairy farms in the Netherlands?

The GHG emission accounting from FarmDyn was used to assess the MAC of a selected number of standalone GHG mitigation options on groups of dairy farms in the Netherlands. The selected GHG mitigation options are based on literature and assumed feasible in the short to medium term. Given assumptions about costs, the GHG mitigation measure 'increased number of lactation periods per cow' and resulting decrease in number of young animals on the farm, is especially cost effective on intensive dairy farms because of the savings in purchased feed and manure disposal costs of the farms. An important finding is that overall the MAC of the selected GHG emission reduction options on extensive dairy farms exceeds the MAC on intensive dairy farms by far.

- What are impacts of different GHG mitigation policies on GHG emission and farm income[1] in the Dutch dairy sector.

Based on the findings of the previous steps, the Dutch version of the FarmDyn model was applied to a sample of dairy farms, grouped by regions, dominant soil type, and livestock density. Five scenarios were tested: the first two involved a subsidization of GHG emission reduction compared to a reference level determined by the base scenario. The subsidization levels were 65 and 130 Euro per ton of CO2eq, respectively. Additional scenarios took the availability of further mitigation options into account, depending on the identified relevant farm characteristics, related MAC of isolated GHG mitigation measures and preferences of farmers: Usage of feed additives, higher number of lactation periods per cow and conversion of arable land into grassland were included for intensive farms, while extensive farms were assumed to rely only on feed additives for this purpose. Even without additional mitigation technologies, emissions across all sample farms can be reduced by almost 20% in the case of the high subsidization rate of 130 Euro/t CO2eq in scenario 2. It should be noted that without additional mitigation technologies between 40% and 60% of the GHG emission reduction is achieved via reduction in number of dairy cows. This reduction of number of dairy cows especially takes place

[1] In this deliverable income is defined as revenue minus paid costs minus depreciation, including extraordinary expenditures and revenues as defined in the Dutch FADN.

on intensive dairy farms. The responsiveness of intensive farms to the subsidy is mainly due to the fact that income per cow tend to be lower at intensive farms because of higher share of purchased feed cost and the cost of manure export as it cannot be brought out on own fields. When the monetary incentive for the reduction of emissions is combined with other mitigation measures on intensive farms, an overall reduction between about 20% and 26% appears to be possible depending on the subsidy rate. In that case between 15% and 30% of the GHG emission reduction is achieved via reduction in number of dairy cows.

The subsidization of GHG emission reductions has a positive impact on farm incomes. Without the subsidy on CO2eq emission reduction farm income would decrease with more than 19% for the average farm, amounting to a decline of 170 million Euro compared to the base value of 881 million Euro at sector level, in the case of a subsidization level of 130 Euro, excluding mitigation options. Reasons are reduced revenues as consequence of the smaller herd sizes and the higher expenditures for purchased concentrates, feed additives, and veterinary costs in the case of the extension of the number of lactation period per cow. Still, total variable costs tend to decline, largely driven by the reduction of purchased roughages (i.e. silage maize) and lower cost for manure exports due to the smaller herds.

- What are policy recommendations?
    - If policy makers want to increase the adoption rate of climate mitigation measures in the short-term, it may be useful to target farmers younger than 45 years old, with full agricultural education level and farms with high livestock density.
    - To increase farmers' attitude towards GHG mitigation measures, the Dutch government and the dairy sector can collaborate:
        - evaluate the advantages and disadvantages of certain climate mitigation measures: promote long-term benefits of mitigating GHG emission
        - stimulate learning from peers
            - On average Dutch dairy farms may increase GHG emission efficiency if farms catch up with their peers, but marginal costs of further and overall GHG emission reduction are high especially on extensive dairy farms in the Netherlands.
        - Organizing farm extension services
        - develop smart applications in calculating the mitigation potential and trade-offs with other farming goals
        - compensate the short-term costs that farmers may encounter.
    - Cost efficient policies affecting heterogenous farms require that policy measures are differentiated by farm type e.g. different GHG emission reduction targets
    - Farming system specific (e.g. dairy farms differentiated by intensity level), budget neutral market-based policies, combining GHG emission reduction subsidies and a tax on initial GHG emission allow policy makers to steer towards extensification pathways.