Supporting Information

Towards a generic analytical framework for sustainable nitrogen management: application for China

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SI text

Five tiers for the cost-benefit analysis

Tier 1: Metrics for exceedance of standards based on scientific effect criteria for environmental emissions or asset quality, e.g., exceedance of air and water quality standards. The critical levels of reactive nitrogen (N_r) concentrations are considered as the safe boundary below which no adverse effects occur and are typically derived from dose-response experiments. In contrast, air quality limit values, such as $PM_{2.5}$ concentrations in ambient air, are set to a threshold for the protection of public health, e.g. the WHO guideline value of 10 μg m^{-3}; however, they do not stipulate that no effects occur below that limit.

Tier 2: Metrics for impacts of nitrogen (N) pollution on human and environmental health, e.g., exacerbation or incidence of respiratory illness, cancers, frequency and extent of harmful algal blooms, or effects on biodiversity or forest vitality. In this tier, the impacts of N_r pollution will be identified, and their priorities are also discussed as their impacts are diverse, with some impacts considered to be weak or difficult to quantify due to unclear effects mechanisms, or limitations to data availability.

Tier 3: Metrics expressing achievement of internationally or nationally agreed policy objectives to assess the effect of policies and interventions; e.g. "distance to policy target" or critical loads/levels thresholds. Pollution mitigation is assessed step by step, while considering financial constraints and technology levels. For instance, NO_x emissions from fossil fuel combustion is highly dependent on the combustion process design and potential after treatment technology installed. A stringent emission standard may be either technologically infeasible or not economically viable.

Tier 4: Aggregated metrics in units more meaningful and easily communicable for the general public, e.g., translation of health impacts to change in (healthy) life expectancy, or species impacts to loss of biodiversity, ecosystem functioning/services. Linking the impact to real damage needs metrics to quantify and make the results comparable across regions or different impact categories. For instance, Disability Adjusted of Life Years (DALY) is a useful metric to make all the impacts on human health comparable.

Tier 5: Metrics of 4 expressed as a loss or gain of prosperity or welfare, in economic or monetary units. To make the different terms of costs and benefits comparable, monetization is one established approach. One measure is desirable only when its related cost is smaller than the aggregated benefits gained by its implementation.

N budgets of 14 subsystems

The input N cascading through and between the 14 subsystems including complex interactions is depicted in Fig. S1, and are indicated by the N output from one subsystem as N input to another subsystem. The figure illustrates the overall picture of N cycling in the 14 subsystems in our model. The total N input to each subsystem varies substantially. N cycling in the most important 6 subsystems: industry, cropland, livestock, human, atmosphere and hydrosphere, has been briefly introduced in the China case study in the main text, thus, we show here a more detailed breakdown of these N fluxes.

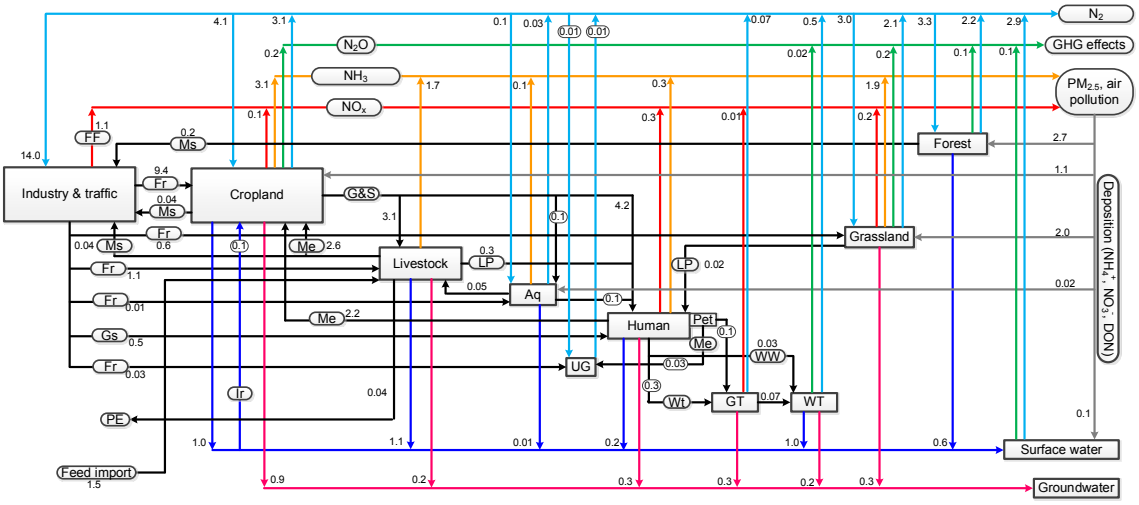

Figure S1. N cycling among the 14 subsystems in China in 1980. ***FF***, fossil fuel combustion; ***Ms***, materials; ***Fr***, fertilizer; ***Gs***, goods; ***PE***, products export; ***Me***, manure; ***G&S***, grain and straw; ***LP***, livestock products; ***Aq***, aquaculture; ***UG***, urban greenland; ***WT***, waste treated; ***GT***, garbage treatment subsystem; ***WW***, wastewater; ***WT***, wastewater treatment subsystem. Unit, Tg N yr^{-1}. Fluxes with a value < 0.01 Tg N yr^{-1} are not listed.

SI methods

Nitrogen budget calculations for the 14 subsystems within the CHANS N cycle model

The N budget of the whole system includes only four N inputs (Haber-Bosch N fixation (HBNF), biological N fixation (BNF), NO_x emitted in fossil fuel combustion (NO_x-FF) and import of N containing products), four N outputs (N_2 emissions, N_r transported to other countries or the ocean via air or water pathways, and export of N containing products), and N_r accumulation (Fig. S2).

In practice, these items can be all calculated at the subsystem level. For instance, the total biological N fixation (BNF) input can be calculated as a sum of BNF input to cropland, grassland, forest, aquaculture and urban green-land. Therefore, the N budgets of the 14 subsystems can be calculated first, then the N input to, output from and accumulation within a country can be extracted to build the overall N balance. The following sections describe the N budgets of the 14 subsystems, with definitions of subsystem boundaries and calculation of each N flux. The calculations all consistently follow mass balance principles, i.e., inputs equal the sum of outputs and accumulation, and if there is interaction between two subsystems—output of one subsystem as input of another subsystem—these two N fluxes should be equal. Further, N inputs to the human subsystem can be extracted to estimate the benefits of N use in a country, and N fluxes lost to the environment (such as NH_3, NO_x, N_2O, and N_r leaching to groundwater) to assess their environmental costs. We provided the original code of the N budgets in the 14 subsystems and the overall N budgets in China from 1980 to 2010 as a case (*SI text*-Model code); all the coefficients such as pathways of N losses and parameters such as recycling ratios of human excretion can be

retrieved from the model code.

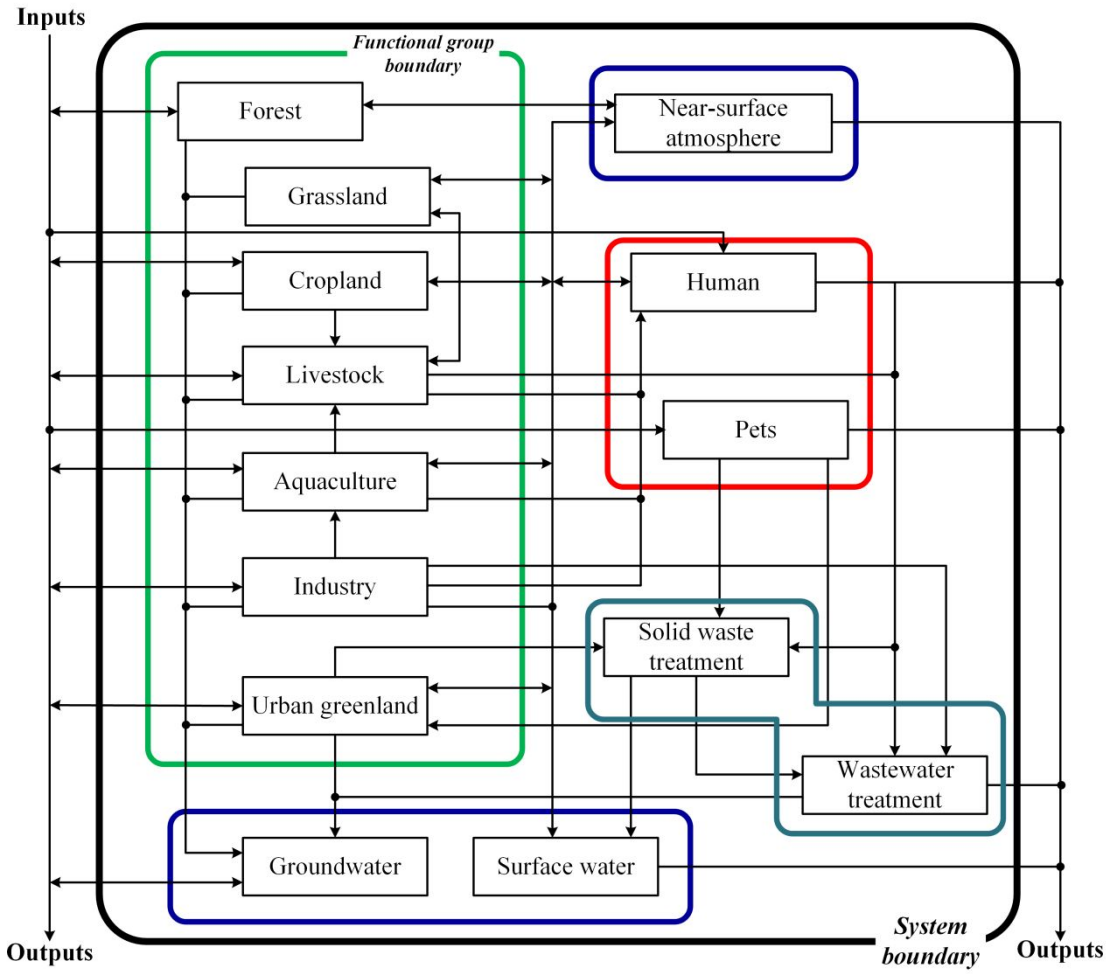

Figure S2. **C**oupled **H**uman **A**nd **N**atural **S**ystems (CHANS) model structure. Arrows represent N fluxes; solid rectangular boxes in black represent systems and subsystems; solid rectangular boxes in colors represent boundaries of functional groups, with green lines representing the processor, red the consumer, cyan the remover, and blue the life-supporter. Within the boundary, the system was divided into 14 subsystems: cropland, grassland, forest, livestock, aquaculture, industry, humans, pets, urban green land, wastewater treatment, solid waste treatment, atmosphere, surface water, and groundwater.

Cropland subsystem (CL). All of the N input to, output from, and accumulation within cropland soils were considered in the CHANS model. Inputs include fertilizer N, BNF, manures, recycled straw, N deposition and irrigation; outputs include grain and straw harvested and removed from the croplands, N losses to air (NH_3, NO, N_2O, N_2) and water (both surface waters and groundwater); N accumulation refers to changes in both the soil organic and inorganic N content. The calculation equations used are as follows:

$$CL_{IN} = CLIN_{Fer} + CLIN_{BNF} + \sum_{i=1}^{2} CLIN_{Exc,i} + CLIN_{Dep} + CLIN_{Irr} + CLIN_{Str} \quad (S1)$$

$$CL_{OUT} = \sum_{i=1}^{4} CLOUT_{Crop,i} + \sum_{i=1}^{5} CLOUT_{Str,i} + \sum_{i=1}^{6} CLOUT_{Loss,i} \quad (S2)$$

where CL_{IN} and CL_{OUT} are the total N input to and output from cropland; $CLIN_{Fer}$ is synthetic fertilizer application; $CLIN_{BNF}$ is the BNF, including symbiotic and non-symbiotic N fixation; $CLIN_{Exc,i}$ is excretion recycled to cropland from both livestock and humans; $CLIN_{Dep}$ is N deposition, including both dry and wet deposition; $CLIN_{Irr}$ is Nr input to cropland from irrigation; $CLIN_{Str}$ is the straw recycled to cropland; $CLOUT_{Crop,i}$ is crop production, including crops used as human food, livestock feed, aquaculture feed and industrial materials; $CLOUT_{Str,i}$ is straw production, including straw used as feed, fuel in rural areas and industrial materials, recycled to cropland, and burned in the field; $CLOUT_{Loss,i}$ is Nr loss during crop production, including NH_3, N_2, N_2O and NO_x emissions, riverine runoff , and leaching to groundwater.

Fertilizer N applied to cropland can be directly obtained from the national statistical data or FAO data. Total BNF is estimated by the symbiotic N_2 fixation rate of leguminous plants with sown area, and non-symbiotic N fixation rate for rice, sugarcane and other crops with their sown area. N deposition is estimated based on the per hectare deposition rate from a synthesis of existing measurements obtained from literature. Irrigation can input considerable amounts of Nr to croplands given the eutrophic surface water and groundwater, and this source is estimated by the total irrigated water volume and average N concentration. Manure inputs to cropland are estimated from the livestock subsystem.

Grain N harvested is estimated by using total production figures and N concentrations for each crop type. The total production of cropland includes five cereals, beans, potatoes, cotton, five oil crops, four hemps, sugarcane, sugarbeet, tobacco, tea, nine fruits, and vegetables. Other crops that are not included above can be given by type, such as other cereals, other fruits, etc. Then, using harvesting indices and N concentrations of straw of different crops, the total harvested N in straw can be estimated. The fate of grains can be assumed as first supplied to humans as food, and the remainder supplied to aquaculture and livestock as feed. The grain supplied to humans and aquaculture can be estimated based on FAO statistics and national data. The fate of straw produced can be estimated as straw used as feed, fuel in rural areas and industrial materials, recycled to croplands, and burned in the field; the proportions of these utilization patterns can be estimated by the synthesis of national statistics and literature data. N losses to air and water are affected by the N input type, land use and climatic zone. N accumulation is calculated as the difference between N inputs and outputs.

Grassland subsystem (GL). The boundary of the grassland subsystem includes both the grasslands and the grazing animals that utilize it, given their tight coupling both in space and function. N inputs to grasslands include BNF, N deposition and fertilizer N application to intensively managed grasslands. Outputs include animal products and N losses to air and water. The in situ excretion and forage grazed by animals are both considered as within-

system N cycling. Nevertheless, both the N fluxes for grazing animals and grassland still can be calculated to supply more information on the integrated grassland subsystem. N accumulation refers to changes in both soil organic and inorganic N contents in grasslands and the difference in livestock biomass N stock between two consecutive years. The calculations are as follows:

$$GL_{IN} = GLIN_{Fer} + GLIN_{BNF} + GLIN_{Dep} \quad (S3)$$

$$GL_{OUT} = GLOUT_{Product,i} + \sum_{i=1}^{6} GLOUT_{Loss,i} \quad (S4)$$

where GL_{IN} and GL_{OUT} are the total N input to and output from the grassland subsystem; $GLIN_{Fer}$ is N fertilizer applied to managed grasslands; $GLIN_{BNF}$ is BNF, symbiotic and non-symbiotic N fixation; $GLIN_{Dep}$ is N deposition, including both dry and wet deposition; $GLOUT_{Product}$ is the animal products from grazing livestock; $GLOUT_{Loss}$ is Nr loss from grasslands, including burning of livestock excreta, NH_3, N_2, N_2O and NO_x emissions, and leaching.

Fertilizer N use on grasslands occurred mainly on artificial grasslands. The BNF and N deposition input to grasslands can be estimated both based on the grassland area and their rates of N input. Degradation of grasslands may reduce the BNF rate and changes in the net primary productivity (NPP) of leguminous plants in grasslands can be used to estimate symbiotic BNF. For non-symbiotic BNF, a constant rate can be estimated. Forage production can be calculated based on the NPP estimates grasslands.

Animal products and the excretion generated on grasslands can be estimated by the same strategy as in the livestock subsystem. The fate of excretion may be recycled to grasslands or burned by herdsmen for cooking and heating in some regions or countries. Similar to croplands, recycled manures can also be lost to the air via NH_3, NO, N_2O and N_2, to surface water via runoff and to groundwater via leaching.

Forest subsystem (FR). Forest includes many types, e.g., evergreen broadleaf, deciduous broad-leaved, mixed conifer and broadleaf, coniferous forest, shrub and bamboo. N inputs to forest subsystem included BNF and N deposition, and the N outputs referred to timber harvested Nr loss to the environment. The calculations are as follows:

$$FR_{IN} = FRIN_{BNF} + FRIN_{Dep} \quad (S5)$$

$$FR_{OUT} = FROUT_{Timber} + \sum_{i=1}^{5} FROUT_{Loss,i} \quad (S6)$$

where FR_{IN} and FR_{OUT} are the total N input and output to the forest; $FRIN_{BNF}$ is BNF, symbiotic and non-symbiotic N fixation; $FRIN_{Dep}$ is N deposition, including both dry and wet deposition; $FROUT_{Timber}$ is timber production; $FROUT_{Loss}$ is Nr loss from forest, including NH_3, N_2 and N_2O emissions, riverine runoff and leaching. N accumulation is calculated as the difference of FR_{IN} and FR_{OUT}.

BNF can be estimated based on the area of each forest type and their N fixation rate. Similar estimation can also be applied to the N input from deposition by using the N deposition

rate. Total timber N harvested can be estimated with a general N concentration of the woods. About half of the N input to forest subsystem is accumulated in the forest. With elevated N deposition input, a proportion of these inputs can leach to the surface water and groundwater. NH_3, N_2O and N_2 emission from different types of forest can be estimated based on the emission rates in field experiments.

Livestock subsystem (LS). To reflect the contribution of grasslands to livestock production, the total livestock production can be split into two categories: 1) grazing animals and 2) non-grazing animals. To simplify the calculation, grazing animals can be assumed to only feed by forage and the other animals are fed grain, straw and food residues. The non-grazing animal feeding operations (NAFO) can be considered as the livestock subsystem, while grazing animals are included in the grassland subsystem. The inputs to NAFO include grain (both domestic and imported), straw, fish feed and food residues, and outputs are animal products and excretion. For the NAFO, animal excretion is partly recycled to cropland as manure except for that lost to air or water. The equations used for the calculation are as follows:

$$LS_{IN} = \sum_{i=1}^{2} LSIN_{Crop} + LSIN_{Fer} + LSIN_{Str} + LSIN_{Aqu} + LSIN_{Res} \quad (S7)$$

$$LS_{OUT} = \sum_{i=1}^{2} LSOUT_{Meat,i} + LSOUT_{Indu} + \sum_{i=1}^{6} LSOUT_{Exc,i} \quad (S8)$$

where LS_{IN} and LS_{OUT} are the total N inputs to and outputs from the livestock subsystem; $LSIN_{Crop}$ is crops used as livestock feed both from domestic production and imports; $LSIN_{Fer}$ is the urea input for straw ammoniation to produce feed; $LSIN_{Str}$ is the straw used as feed; $LSIN_{Aqu}$ is the fishmeal used as livestock feed; $LSIN_{Res}$ is the food residue used for feed, mainly in rural households and from restaurants; $LSOUT_{Meat,i}$ is livestock products, including meat, milk and eggs, which are transferred to the human subsystem or exported; $LSOUT_{Indu}$ is the livestock product that is not used as food, including cocoons, leather, wool, etc.; $LSOUT_{Exc,i}$ is livestock excretion, which is recycled to cropland, lost through riverine runoff, leached to groundwater, NH_3 volatilization, and N_2 and N_2O emission. N accumulation in the livestock subsystem is considered as the difference in livestock biomass N stock between two consecutive years.

Livestock N production can be estimated based on the total production and the N concentration of each livestock product. Based on the livestock raised each year and the excretion generated per animal, the total excretion of N by livestock can be estimated. Considering the livestock N stock between two consecutive years combined with livestock production and excretion, the total demand of feed N in one year can be estimated. The feed demand is first satisfied by grain transferred from croplands, followed by straw and the fertilizer used for straw treatment (to increase the palatability and protein content), fishmeal supplied from aquaculture, and food residues; if there is still a gap between demand and supply, feed imports can be assumed to fill this gap; in contrast, if the demand is smaller than the supply, feed (counted as grain) export occurred. International trade data from national

data providers can be used to crosscheck and validate the estimates of feed imports.

A large proportion of the livestock N excretion is emitted as NH_3 before the manure is applied to cropland. The remainder of the excretion go to cropland, runoff to surface waters, or leaching to groundwater.

Aquaculture subsystem (AQ). Aquaculture refers to both natural and cultivated fish production. The production from natural fishery is considered as an input to the subsystem. For the cultivated fishery, feed, N fertilizer and N deposition are considered as inputs. Besides the aquaculture products harvested, the input N lost to the environment via runoff, denitrification and volatilization.

$$AQ_{IN} = AQIN_{Crop} + AQIN_{Fer} + AQIN_{Fishery} + AQIN_{Dep} \quad (S9)$$

$$AQ_{OUT} = \sum_{i=1}^{3} AQOUT_{Meat,i} + \sum_{i=1}^{5} AQOUT_{Loss,i} \quad (S10)$$

where LS_{IN} and LS_{OUT} are the total N input and output to aquaculture subsystem; $AQIN_{Crop}$ is crop that used as aquaculture feed; $AQIN_{Fer}$ is fertilizer input to aquaculture subsystem; $AQIN_{Fishery}$ is natural fishery; $AQIN_{Dep}$ is N deposition, including both dry and wet deposition; $AQOUT_{Meat}$ is aquaculture production, including fish, shrimp, crab, shellfish, algae, and other aquatic products that can be transferred to human or livestock subsystems, or exported to external systems; $AQOUT_{Loss}$ is N_r loss during aquaculture production, including emissions of N_2, N_2O and NH_3, riverine runoff and sedimentation. N accumulation is calculated as the difference of AQ_{IN} and AQ_{OUT}.

Aquaculture production can be estimated based on the total production and the N concentration of each aquaculture species. Aquaculture feed use can be estimated based on the average feed conversion ratio (FCR), and the N fertilizer use can be estimated as a proportion of the total feed use. Total N deposition can be estimated based on the total aquaculture area and the N deposition rate per hectare. The aquaculture production can be assumed to satisfy domestic human need first, and the rest is used as livestock feed, except the amount used for export. The N surplus can be calculated as the total N input minus the N harvested in aquaculture production. Then, the emissions of NH_3, N_2 and N_2O and runoff can be estimated as a proportion of total N surplus, respectively.

Industry subsystem (ID). The industrial subsystem is an N processor system, which does not accumulate N in the system. The main N inputs are N_2 for the HBNF, fossil fuel for energy supply and agricultural nonfood goods for processing. The N outputs are N fertilizer, nonfood goods, and N losses during the industrial production processes.

$$ID_{IN} = IDIN_{N2} + \sum_{i=1}^{3} IDIN_{Crop,i} + IDIN_{Str} + \sum_{i=1}^{4} IDIN_{LS,i} + IDIN_{Timber} + IDIN_{Fuel} \quad (S11)$$

$$ID_{OUT} = IDOUT_{Fer} + \sum_{i=1}^{m} IDOUT_{NA,i} + \sum_{i=1}^{n} IDOUT_{NB,i} + \sum_{i=1}^{4} IDOUT_{Loss,i} \quad (S12)$$

where LS_{IN} and LS_{OUT} are the total N input and output to aquaculture subsystem; $IDIN_{N2}$ is HBNF in factories; $IDIN_{Crop,i}$ is agricultural product transferred to industry, including cotton, hemp, tobacco, etc.; $IDIN_{Str}$ is straw transferred to industry for material production; $IDIN_{LS,i}$ is the livestock product transferred to industry, including cocoon, leather, wool, etc.; $IDIN_{Timber}$ is timber from the forest subsystem used for production of furniture and other wood products; $IDIN_{Fuel}$ fossil fuel combustion during industrial production, calculated as:

$$IDIN_{Fuel} = \sum_{i=1,j=1}^{n} (Fuel_{i,j} \times NOxN_{i,j}) \quad (S13)$$

where $Fuel_{i,j}$ is the consumption of fuel j in sector i; $NOxN_{i,j}$ is the emission of NO_x in sector i when consumed per unit fuel j; the sector i includes electrical, construction, gas production, smelting, commercial, transportation, and other industries, fuel j includes coal, oil, natural gas, coke, gasoline, kerosene, diesel and fuel oil.

$IDOUT_{Fer}$ is N_r fertilizer production, which is used on croplands, artificial grasslands, urban lawns, aquaculture, and livestock feed production; $IDOUT_{NA,i}$ comprises industrial products made from synthetic NH_3 (N_A), including synthetic fibers, drugs, nitrile rubber, synthetic detergents, plastics, nitric acid, explosives and other products, not including fertilizer; $IDOUT_{NB,i}$ covers industrial products made from the materials transferred from agriculture and forestry (N_B), including cotton, hemp, tobacco, silk, leather, sheepskin, wool, wood furniture, etc.; $IDOUT_{Loss,i}$ is the N_r loss during industrial production, including wastewater discharge, NO_x emissions, denitrification (both N_2 and N_2O) in industrial wastewater treatment plants. The industrial subsystem is only considered as a processing center, thus, we assume that there is no N accumulation in industrial subsystem.

Urban green-land subsystem (UG). The urban green-land subsystem is composed of two parts: urban lawn and forests including shrubs. Urban lawn has similar N cycling as upland, and urban forest areas are assumed to have similar conditions as natural forests. For urban lawn, N fertilizer is an important input during lawn maintenance. Part of pet N excretion is also returned to urban lawn. Other N inputs including N deposition and BNF are applied both to urban lawn and forest areas. The N inputs to the urban green-land are important to the growth of grass and trees. Lawn mowing and tree pruning remove N uptake and output its N_r as green waste. Other N outputs mainly refer to the N loss after N is applied to green-land.

$$UG_{IN} = UGIN_{Fer} + UGIN_{PetExc} + UGIN_{BNF} + UGIN_{Liter} + UGIN_{Dep} \quad (S14)$$

$$UG_{OUT} = \sum_{i=1}^{3} UGOUT_{Clip,i} + \sum_{i=1}^{5} UGOUT_{Loss,i} \quad (S15)$$

where UG_{IN} and UG_{OUT} are the total N input and output to urban green land; $UGIN_{Fer}$ is fertilizer applied to urban lawn; $UGIN_{PetExc}$ is pet excretion recycled to urban lawn; $UGIN_{BNF}$ is BNF in urban green land; $UGIN_{Liter}$ is the liter recycled back during lawn and tree clipping; $UGIN_{Dep}$ is N deposition, including both dry and wet deposition; $UGOUT_{Clip,i}$ the

N removal through lawn and tree clipping, which is recycled to green land, or sent to landfill or garbage burning; $UGOUT_{Loss,i}$ is Nr loss from green land, including NH_3 volatilization, riverine runoff, N_2 and N_2O emission, and leaking to groundwater. N accumulation is calculated as the difference of UG_{IN} and UG_{OUT}.

Human subsystem (HM). The human subsystem mainly refers to the consumption of food, non-food goods and energy. Therefore, the N inputs to human subsystem include all the food items such as grain, livestock and aquaculture products, agricultural, forestry and industrial goods such as cotton and nylon, biomass and fossil fuel for energy use. Part of the input food is calculated as a loss through food waste, and the rest is assumed to be discharged as excretion. For the non-food goods, structural ones usually accumulate in human settlements or are sent to landfill as solid waste, and non-structural ones are released to the environment once used. For energy use, emissions of NO_x, NH_3, N_2O and N_2 can be released to the air during the energy generation process.

$$HM_{IN} = \sum_{i=1}^{3} HMIN_{Food,i} + \sum_{i=1}^{2} HMIN_{Indu,i} + HMIN_{Fuel} + HMIN_{Str} \quad (S16)$$

$$HM_{OUT} = \sum_{i=1}^{4} HMOUT_{WW,i} + \sum_{i=1}^{2} HMOUT_{WG,i} + \sum_{i=1}^{2} HMOUT_{NOx,i} \quad (S17)$$

where HM_{IN} and HM_{OUT} are the total N input and output to human subsystem; $HMIN_{Food,i}$ is human food consumption, including crop, livestock product (meat and milk) and aquaculture product (fish and others); $HMIN_{Indu,i}$ is human industrial product consumption, including N_A and N_B; $HMIN_{Fuel}$ is the NO_x emission from domestic fossil fuel consumption; $HMIN_{Str}$ is straw used as biofuel for cooking; $HMOUT_{WW,i}$ is human excretion, which can be recycled to cropland, sent to wastewater treatment plants, discharged to surface water or leaching to groundwater; $HMOUT_{WG,i}$ is the garbage, including food waste and industrial product abandoned; $HMOUT_{NOx,i}$ is the NO_x emission from fuel consumption, including $HMIN_{Fuel}$ and $HMIN_{Str}$. N accumulation in human subsystem is relates to the increase of N-contained in human bodies, and industrial products accumulated in human settlements.

The per capita human food consumption can be obtained from FAO data, human goods and fossil fuel consumption can be retrieved from national statistics. Straw burning refers to straw used for energy in rural area. The proportion of the four destinations of human excretion can be compiled from investigations or literatures. About 10-30% of the food supply is lost as food waste, and for rural areas can be assumed to be reused as livestock feed, whereas in urban areas is sent to garbage treatment including composting. All nonstructural non-food goods are lost to the environment, whereas half of the structural non-food goods are considered to be sent to the garbage treatment at the end of their economic life.

$$HMIN_{Fuel} = \sum_{i=1,j=1}^{n} (Fuel_{i,j} \times NOxN_{i,j}) \quad (S18)$$

where $Fuel_{i,j}$ is the consumption of fuel j in sector i; $NOxN_{i,j}$ is the emission of NO_x in

sector i when consumed per unit fuel j; the sector i includes electrical, heating, cooking and other household activities, fuel j includes coal, oil, natural gas, coke, gasoline, kerosene, diesel and fuel oil. NO_x emission from biomass burning can be estimated based on the NO_x emission factors per straw burning.

Pet subsystem (PT). The pet subsystem is an affiliated subsystem of the human system. It does not produce any food, goods or energy for human consumption, but consumes these products in the same way as humans. Only dogs and cats are considered here; others, such as reptiles or gerbils are exclude owing to small numbers.

$$PT_{IN} = \sum_{i=1}^{2} PTIN_{Feed,i} \quad (S19)$$

$$PT_{OUT} = \sum_{i=1}^{2} PTOUT_{Waste,i} \quad (S20)$$

where PT_{IN} and PT_{OUT} are the total N input and output to pet subsystem; $PTIN_{Feed,i}$ is pet feed input, including dog and cat feed; $PTOUT_{Waste,i}$ is pet excretion, which is sent to landfill or recycled to urban green land (6). The numbers of dogs and cats can be estimated based on the numbers of households and pet ownership rates in both rural and urban area. No N accumulation is assumed in this subsystem.

Wastewater treatment subsystem (WT). WT subsystem is an N removing system that treats liquid waste to reduce its environmental impacts. The inputs refer to all the waste water collected and sent to treatment facilities, and the outputs refer to the N loss from this subsystem such as N_2 emission. No N_r accumulation was considered in this subsystem, only N removal.

$$WT_{IN} = WTIN_{HM} + WTIN_{LS} + WTIN_{GT} + WTIN_{Rain} \quad (S21)$$

$$WT_{OUT} = WTOUT_{Den} + WTOUT_{NH3} + WTOUT_{Lea,runoff} + WTOUT_{Slu} \quad (S22)$$

where WT_{IN} and WT_{OUT} are the total N input and output to wastewater treatment subsystem; $WTIN_{HM}$, $WTIN_{LS}$, $WTIN_{GT}$ and $WTIN_{Rain}$ are the domestic wastewater, livestock excretion, landfill leachate treated in wastewater treatment plant and rain in urban area that leaches to the wastewater collecting system, respectively; $WTOUT_{Den}$ is the denitrification in the wastewater treatment plant, including both N_2 and N_2O emissions; $WTOUT_{Lea,runoff}$ is the N_r leaching during the wastewater transferred to the wastewater treatment plant and discharge to rivers after treatment; $WTOUT_{Slu}$ is the N_r contained in the sludge after treatment.

Garbage treatment subsystem (GT). The GT subsystem is an N removing system that treats solid waste to reduce its environmental impacts. The inputs refer to all the waste sent to the treatment facilities, and the outputs refer to the N losses from this subsystem such as leachate or atmospheric emissions. N_r accumulation was considered in this subsystem owing

to landfill.

$$GT_{IN} = GTIN_{UG} + GTIN_{HM} + GTIN_{PT} \quad (S23)$$

$$GT_{OUT} = GTOUT_{Lea} \quad (S24)$$

where GT_{IN} and GT_{OUT} are the total N input and output to garbage treatment subsystem; $GTIN_{UG}$ is the green waste sent to landfill from urban green land subsystem; $GTIN_{HM}$ is garbage from human subsystem; $GTIN_{PT}$ is pet excretion sent to landfill; $GTOUT_{Lea}$ is the Nr contained in garbage released to groundwater.

Surface water subsystem (SW). The SW system receives N_r inputs from other subsystems, and it can also transfer N_r to other countries/oceans through drainage. All the rivers, lakes and wetlands that can receive water flowing into can be considered. No N_r accumulating in this subsystem is assumed.

$$SW_{IN} = \sum_{i=1}^{9} SWIN_{Sub,i} \quad (S25)$$

$$SW_{OUT} = SWOUT_{Irr} + SWOUT_{Den} + SWOUT_{Exp} \quad (S26)$$

where SW_{IN} and SW_{OUT} are the total N input and output to surface water subsystem; $SWIN_{Sub,i}$ is the N_r transferred from other 9 subsystems; including cropland, livestock, aquaculture, forest, industry, urban green land, human, wastewater treatment, and atmospheric deposition. $SWOUT_{Irr}$ is the irrigation losses to cropland; $SWOUT_{Den}$ is denitrification in surface water, including both N_2 and N_2O emission; $SWOUT_{Exp}$ is the Nr transferred to ocean via rivers.

Atmosphere subsystem (AT). AT solely receives N_r input from other subsystems, and it can also transfer N_r to other countries/oceans through atmospheric circulation and deposition; no N_r accumulation is assumed for this subsystem. Thus, the input N is either transferred to different countries or deposited to the land area.

$$AT_{IN} = \sum_{i=1}^{13} ATIN_{Item,i} \quad (S27)$$

$$AT_{OUT} = ATOUT_{Dep} + ATOUT_{Exp} \quad (S28)$$

where AT_{IN} and AT_{OUT} are the total N input and output to near-surface atmosphere subsystem; $ATIN_{Item,i}$ is the N_r emission from other subsystems to near-surface atmosphere, mainly NH_3 and NO_x, including emissions from industrial fossil fuel combustion, domestic fossil fuel combustion, NH_3 volatilization from cropland, livestock, aquaculture, grassland and urban green land, straw burning as biofuel, straw burning in field, garbage burning, and N_2O emissions; $ATOUT_{Dep}$ is N deposition, including both dry and wet deposition; $ATOUT_{Exp}$ is the Nr transferred to surrounding areas through atmospheric circulation.

Groundwater subsystem (GW). GW receives N_r inputs from other subsystems. All the groundwater that can receive water influx is considered. Owing to the few linkages between

the groundwater subsystem and other parts of global water cycles, all the input N_r is assumed to accumulate in this subsystem, except losses for irrigation through pumping of groundwater.

$$GW_{IN} = \sum_{i=1}^{6} GWIN_{Item,i} \quad (S29)$$

$$GW_{OUT} = GWOUT_{Irr} \quad (S30)$$

where GW_{IN} and GW_{OUT} are the total N input and output to groundwater subsystem; $GWIN_{Item,i}$ is Nr input to groundwater from other subsystems; including N_r leaching from cropland, grassland, livestock, urban lawn, wastewater, landfill, etc.; $GWOUT_{Irr}$ is irrigation N pumping from groundwater.

SI Tables

Table S1 Data (D) sources and main parameters (P) used in the N balance calculation

D/P	Description	Unit	Value	Reference /note
For cropland				
D1	Fertilizer applied	Tg N yr^{-1}	See NBSC	[1]
D2	Crop yield	Tg yr^{-1}	See NBSC	[1]
D3	Irrigation	10^9 m^3	See NBSC	[1]
P1	Symbiotic N fixation rate	kg N ha^{-1} yr^{-1}	115	[2]
P2	Non-symbiotic N fixation rate	kg N ha^{-1} yr^{-1}	Paddy field: 33; sugar can: 25; Other: 15	[2, 3]
P3	Livestock excretion recycled ratio	%	~40	[4, 5]
P4	Human excretion recycled ratio	%	Table S10	Table S10
P5	N deposition	kg N ha^{-1} yr^{-1}	21.8 (7.7)	[6]
P5	N concentration of irrigation	mg N L^{-1}	1.5 (0.2)	[7]
P6	Grain N content	%	Table S2	Table S2
P7	Straw N content	%	Table S2	Table S2
P8	Harvest index	-	Table S2	Table S2
P9	Fate of straw	%	Table S3	Table S3
P10	N loss ratio	%	Table S4	Table S4
For grassland				
P11	Fertilization rate on artificial grassland	kg N ha^{-1} yr^{-1}	100	[8]
P12	Non-symbiotic N fixation rate	kg N ha^{-1} yr^{-1}	5	[9]
P13	Grass N content	%	2.4	[10]

P14	Volatilization rate of manure input	%	20	[11]
P15	Burning rate of dry manure	%	20 (15)	[12, 13]
P16	N leaching rate of N input	%	5	[14]
P17	Denitrification rate of N input	%	20	[15]
P18	N_2O emission rate of N input	%	1.3	[11]
For forest				
P19	Wood N content	%	Table S5	Table S5
P20	Symbiotic N fixation rate	kg N ha^{-1} yr^{-1}	Table S5	Table S5
P21	Non-symbiotic N fixation rate	kg N ha^{-1} yr^{-1}	Table S5	Table S5
P22	Denitrification rate	kg N ha^{-1} yr^{-1}	Table S5	Table S5
P23	Runoff rate	kg N ha^{-1} yr^{-1}	Table S5	Table S5
P24	N_2O emission rate	kg N ha^{-1} yr^{-1}	Table S5	Table S5
For Livestock				
D4	Livestock production	Tg yr^{-1}	See FAO	[16]
P25	N content of livestock products	%	Table S6	Table S6
P26	N excreta rate for animal	kg N $capita^{-1}$ yr^{-1}	Table S7	Table S7
P27	NH_3 emission factor for animal	kg N $capita^{-1}$ yr^{-1}	Table S7	Table S7
P28	Nr leaching rate of excreta	%	5	[14]
P29	Nr runoff rate of excreta	%	30	[4, 17]
For Aquaculture				
D5	Aquaculture production	Tg yr^{-1}	See NBSC	[1]
P30	Ratio of feed to products	kg N (kg N)$^{-1}$	1.8	[18]
P31	Ratio of fertilizer to feed	%	20	[19, 20]
P32	N content of aquaculture products	%	Fish: 3.0; shrimp (crab): 2.9; shellfish: 2.1, algae: 3.7; other: 2.9	[21]
P33	Volatilization rate	%	15	[18]
P34	Runoff rate	%	10	[19]
P35	Denitrification rate	%	50	[14]
P36	N_2O emission rate	%	1.25	[11]
For Industry				
D6	Haber-Bosch N fixation	Tg N yr^{-1}	See NBSC	[1]
D7	Industrial products	Tg yr^{-1}	See NBSC	[1]

D8	Fossil fuel consumption	Tg yr^{-1}	See NBSC	[1]
D9	Wastewater discharge	Gg N yr^{-1}	See NBSC	[1]
P37	Industrial product N content	%	Table S8	Table S8
P38	Nr leaching rate of wastewater	%	9	[14, 22]
P39	NO_x emission factors	g N kg^{-1}	Table S9	Table S9
For Urban green-land				
P40	Fertilization rate to urban lawn	kg N ha^{-1} yr^{-1}	300	[23]
P41	Ratio of pet excreta back to lawn	%	75	[24]
P42	Biological N fixation	kg N ha^{-1} yr^{-1}	18	[25]
P43	N loss ratio	%	Table S4	following upland
For Human				
D10	Population	billion	See NBSC	[1]
D11	Urbanization	%	See NBSC	[1]
P44	Food consumption	kg N $capita^{-1}$ yr^{-1}	Urban: 5.5 (5.2); rural: 4.4 (4.9)	[1, 26]
P45	Excretion discharge	kg N $capita^{-1}$ yr^{-1}	Urban: 5.5 (5.2); rural: 4.4 (4.9)	Same with food eaten
P46	NH_3 emission factor	kg N $capita^{-1}$ yr^{-1}	Urban: 0.3; rural: 0.5	[27]
P47	Excretion leaching ratio	%	9	[25]
P48	Fate of human excretion	%	Table S10	Table S10
P49	Food waste ratio	%	8.1	[28]
For Pet				
P50	Food consumption	kg N $capita^{-1}$ yr^{-1}	Dog: 4.1; cat: 1.2	[25]
P51	Ratio of excretion to lawn	%	Dog: 100; cat: 50	[25]
P52	Ratio of excretion to landfill	%	Cat: 50	[25]
For Wastewater treatment				
P53	Wastewater leaching ratio	%	9	[15]
P54	Wastewater denitrification ratio	%	30	[29]
P55	N_2O emission ratio	%	1.25	[25]
For Surface water				
P56	Denitrification ratio of N input	%	50	[30, 31]

P57	N_2O emission ratio	%	1.25	[11]

436 * The value outside the parentheses represents the data in 2010; the value in the parentheses
437 represents the data in 1980.
438
439 **Table S2** N concentrations in grain and straw and the harvest index

Crop	Grain N concentration (%)	Straw N concentration (%)	Harvest index
Rice	1.14	0.75	0.43
Wheat	2.10	0.52	0.37
Corn	1.60	0.58	0.44
Millet	1.92	0.73	0.37
Broomcorn	1.75	0.72	0.40
Beans	5.99	1.93	0.43
Potatoes	0.26	3.00	0.67
Cotton	0.21	1.59	0.38
Peanut	4.00	1.80	0.43
Rape	3.48	0.67	0.25
Gingili	3.48	0.67	0.15
Sunflower	4.08	1.19	0.31
Sesame	3.48	0.67	0.15
Hemp	0.75	0.34	0.36
Sugarcane	0.59	0.67	0.91
Sugarbeet	0.24	0.67	0.91
Tobacco	1.53	0.75	0.49
Tea	3.5		
Apple	0.03		
Citrus	0.11		
Pear	0.06		
Grape	0.08		
Banana	0.22		
Persimmon	0.01		
Date	0.43		
Pineapple	0.22		
Melons	0.16		
Vegetable	0.24		

440 Note, fresh weight for fruits and vegetable, and dry weight for others.
441 Reference: [21, 32-34]
442
443 **Table S3** Proportions of straw utilization in China over the past three decades

Utilization	Proportion

	1980	1990	2000	2010
Recycle to cropland	0.07	0.13	0.22	0.28
Livestock feed	0.27	0.25	0.23	0.24
Domestic energy	0.56	0.39	0.31	0.26
Industrial materials	0.01	0.02	0.04	0.06
Burning in field	0.10	0.21	0.19	0.16
Total	1.00	1.00	1.00	1.00

Reference: [1, 32]

Table S4 The loss rate (%) of N applied as inorganic and organic N in China's croplands, divided into the south and north regions

N loss	Synthetic N input				Organic
	Upland		Paddy field		
	North	South	North	South	
NH_3 emission	21.3	11.0	16.0	16.0	23.0
Denitrification	3.2	25.3	33.0	36.4	15.0
Leaching	7.3	3.2	0.5	1.2	4.0
Runoff	3.5	11.0	5.2	5.2	5.0
N_2O emission	1.1	1.1	0.4	0.4	1.0
NO emission	0.7	0.7	0.1	0.1	0.7

References: [11, 35-37]

Table S5 N fluxes in China's different types of forests

Forest types	N rates (kg N ha^{-1} yr^{-1})					Wood N content (%)
	Symbiotic N fixation	Non-symbiotic N fixation	Denitrifi-cation	Run off	N_2O	
Evergreen broad-leaved	5.0	12.0	6.4	5.0	1.2	0.2
Deciduous	5.0	3.5	4.5	3.0	0.8	0.2
Coniferous and mixed	5.0	2.5	3.3	2.0	0.5	0.2
Coniferous forest	5.0	1.6	0.2	1.0	0.3	0.1
Bush	5.0	4.9	3.6	2.8	0.7	0.3
Bamboo	5.0	4.9	3.6	2.8	0.7	0.4

References: [25, 38-40]

Table S6 N concentrations in livestock products

Product	N concentration (%)	Product	N concentration (%)
Pork	2.1	Egg	2.1
Beef	3.2	Duck egg	2.0

Lamb	3.0	Goose	1.8
Donkey	3.4	Milk	0.5
Horsemeat	3.2	Goat's milk	0.2
Rabbit	3.2	Honey	0.1
Chicken	3.1	Silkworm cocoon	3.4
Duck	2.5	Sheepskin	8.4
Goose	2.9	Leather	12.6
Game meat	2.9	Wool	12.2
Turkey	3.2		

References: [21]

Table S7 Livestock N excretion rates (kg N capita^{-1} yr^{-1})

Livestock	Total Excretion	Total NH_3	NH_3 (Storage)	NH_3 (Manure)	NH_3 (Grazing)
Dairy cow	74.40	26.36	12.48	12.98	1.80
Draft cow	50.00	21.02	10.48	10.55	NA
Beef cattle	45.87	18.60	8.69	9.91	NA
Horse	68.64	18.60	6.11	7.50	5.00
Donkey/mule	68.64	18.60	6.11	7.50	5.00
Sheep/Goat	11.23	4.18	0.63	2.95	0.60
Pig	4.87	2.33	1.43	0.90	NA
Layers	0.82	0.41	0.24	0.17	NA
Rabbits	0.45	0.20	0.10	0.09	NA
Ducks/Geese	0.47	0.25	0.16	0.08	NA
Chicken	0.09	0.04	0.03	0.02	NA
Camel	55	10.5	NA	NA	10.5
Buffalo	45	8.7	NA	NA	8.7

NA, not applicable

References: [5, 25]

Table S8 N contents of major N-containing industrial products

Industrial		Agricultural	
Product	N content (%)	Product	N content (%)
Detergent	0.5	Leather	12.6
Drugs	5.0	Cotton	3.0
Dynamite	18.0	Bast	0.8
Nitrate	22.0	Sheepskin	8.4
Plastic	0.5	Silk	3.4
Synthetic dyes	15.0	Tobacco leaf	1.5
Synthetic fiber	10.0	Wood furniture	0.3
Synthetic rubber	0.5	Wool	12.2

References: [41]

Table S9 NO_x emission factors of fossil fuel combustion in different economic sectors (g N kg^{-1})

Sector	Coal	Coke	Crude oil	Gasoline	Kerosene	Diesel	Natural gas*
Business	1.1	1.4	0.9	5.1	1.4	0.8	0.4
Coking or refining	0.3		0.1				
Construction	2.3	2.7		5.1	2.3	2.9	0.6
Electricity	3.0		2.2	5.1	6.5	8.3	1.2
Industry	2.3	2.7	1.5	5.1	2.3	2.9	0.6
Residents	0.6	0.7	0.5	5.1	0.8	1.0	0.4
Transportation	2.3	2.7	1.5	7.4	8.3	16.5	0.6
Other	1.1	1.4	0.9	5.1	1.4	1.8	0.4

* Unit of emission is g N m^{-3}.

References: [42]

Table S10 Excretion utilization (%) in urban and rural areas

Fate of excreta	1980	1990	2000	2010
Urban sewage treatment	5.0	14.9	34.3	75.0
Urban excretion recycled	90.0	69.4	41.2	5.0
Urban excretion discharged	5.0	15.8	24.6	20.0
Urban excretion leached	9.0	9.0	9.0	9.0
Rural sewage treatment	0.0	1.5	4.2	7.2
Rural excretion recycled	95.0	93.8	77.1	53.4
Rural excretion discharged	5.0	4.7	18.7	39.4
Rural excretion leached	9.0	9.0	9.0	9.0

References: [7, 43]

SI text-Model code

Aquaculture subsystem

```
Aquaculture(t) = Aquaculture(t - dt) + (AQIN - AQOUT) * dt
INIT Aquaculture = 0
INFLOWS:
AQIN = AQIN\BNF+AQIN\Deposition+AQIN\Fertilizer+AQIN\Grain
OUTFLOWS:
AQOUT = ARRAYSUM(AQOUT\Fish[*])+AQOUT\N2+AQOUT\N2O+AQOUT\NH3+AQOUT\Runoff
AQIN\BNF = ARRAYSUM(AQOUT\Fish[*])*(1-Cultivated_ratio)
AQIN\Deposition = Aquacultural_area*Deposition_rate/10^5
AQIN\Fertilizer = AQIN\Grain/80*15
```

AQIN\Grain = ARRAYSUM(AQOUT\Fish[*])*Cultivated_ratio*1.8
AQOUT\Fish[Aq_species] =
Aquacultural_index[Aq_species,Aq_production]*Aquacultural_index[Aq_species,Aquacultural_N_content]/10^4
AQOUT\N2 = Aq_total_loss*0.5
AQOUT\N2O = Aq_total_loss*0.0125
AQOUT\NH3 = Aq_total_loss*0.15
AQOUT\Runoff = Aq_total_loss*0.1
Aq_total_loss = AQIN-arraysum(AQOUT\Fish[*])
Aquacultural_area = GRAPH(TIME)
(1980, 286), (1981, 317), (1982, 319), (1983, 322), (1984, 326), (1985, 321), (1986, 339), (1987, 345), (1988, 351), (1989, 355), (1990, 366), (1991, 378), (1992, 392), (1993, 405), (1994, 419), (1995, 433), (1996, 446), (1997, 460), (1998, 474), (1999, 488), (2000, 501), (2001, 515), (2002, 529), (2003, 543), (2004, 556), (2005, 570), (2006, 584), (2007, 598), (2008, 611), (2009, 608), (2010, 626)
Aquacultural_index[Fish1,Aq_production] = GRAPH(TIME)
(1980, 350), (1981, 361), (1982, 406), (1983, 427), (1984, 484), (1985, 551), (1986, 646), (1987, 745), (1988, 804), (1989, 856), (1990, 928), (1991, 997), (1992, 1116), (1993, 1268), (1994, 1507), (1995, 1777), (1996, 2001), (1997, 2289), (1998, 2481), (1999, 2575), (2000, 2606), (2001, 2644), (2002, 2732), (2003, 2824), (2004, 2911), (2005, 2651), (2006, 2715), (2007, 2800), (2008, 2863), (2009, 2991), (2010, 3132)
Aquacultural_index[Fish1,Aquacultural_N_content] = GRAPH(TIME)
(1980, 2.99), (1981, 2.99), (1982, 2.99), (1983, 2.99), (1984, 2.99), (1985, 2.99), (1986, 2.99), (1987, 2.99), (1988, 2.99), (1989, 2.99), (1990, 2.99), (1991, 2.99), (1992, 2.99), (1993, 2.99), (1994, 2.99), (1995, 2.99), (1996, 2.99), (1997, 2.99), (1998, 2.99), (1999, 2.99), (2000, 2.99), (2001, 2.99), (2002, 2.99), (2003, 2.99), (2004, 2.99), (2005, 2.99), (2006, 2.99), (2007, 2.99), (2008, 2.99), (2009, 2.99), (2010, 2.99)
Aquacultural_index[Shrimp,Aq_production] = GRAPH(TIME)
(1980, 47.2), (1981, 46.9), (1982, 52.6), (1983, 54.7), (1984, 64.6), (1985, 76.2), (1986, 83.1), (1987, 92.0), (1988, 112), (1989, 115), (1990, 117), (1991, 130), (1992, 140), (1993, 152), (1994, 191), (1995, 212), (1996, 241), (1997, 274), (1998, 319), (1999, 348), (2000, 385), (2001, 403), (2002, 433), (2003, 437), (2004, 466), (2005, 422), (2006, 467), (2007, 501), (2008, 499), (2009, 532), (2010, 559)
Aquacultural_index[Shrimp,Aquacultural_N_content] = GRAPH(TIME)
(1980, 2.86), (1981, 2.86), (1982, 2.86), (1983, 2.86), (1984, 2.86), (1985, 2.86), (1986, 2.86), (1987, 2.86), (1988, 2.86), (1989, 2.86), (1990, 2.86), (1991, 2.86), (1992, 2.86), (1993, 2.86), (1994, 2.86), (1995, 2.86), (1996, 2.86), (1997, 2.86), (1998, 2.86), (1999, 2.86), (2000, 2.86), (2001, 2.86), (2002, 2.86), (2003, 2.86), (2004, 2.86), (2005, 2.86), (2006, 2.86), (2007, 2.86), (2008, 2.86), (2009, 2.86), (2010, 2.86)
Aquacultural_index[Shellfish,Aq_production] = GRAPH(TIME)
(1980, 25.9), (1981, 30.2), (1982, 34.3), (1983, 39.4), (1984, 44.3), (1985, 50.7), (1986, 71.5), (1987, 94.2), (1988, 120), (1989, 145), (1990, 155), (1991, 167), (1992, 215), (1993, 305), (1994,

339), (1995, 413), (1996, 901), (1997, 861), (1998, 916), (1999, 1002), (2000, 1085), (2001, 1131), (2002, 1176), (2003, 1164), (2004, 1165), (2005, 1054), (2006, 1098), (2007, 1119), (2008, 1123), (2009, 1172), (2010, 1224)

Aquacultural_index[Shellfish,Aquacultural_N_content] = GRAPH(TIME)

(1980, 2.14), (1981, 2.14), (1982, 2.14), (1983, 2.14), (1984, 2.14), (1985, 2.14), (1986, 2.14), (1987, 2.14), (1988, 2.14), (1989, 2.14), (1990, 2.14), (1991, 2.14), (1992, 2.14), (1993, 2.14), (1994, 2.14), (1995, 2.14), (1996, 2.14), (1997, 2.14), (1998, 2.14), (1999, 2.14), (2000, 2.14), (2001, 2.14), (2002, 2.14), (2003, 2.14), (2004, 2.14), (2005, 2.14), (2006, 2.14), (2007, 2.14), (2008, 2.14), (2009, 2.14), (2010, 2.14)

Aquacultural_index[Alga,Aq_production] = GRAPH(TIME)

(1980, 26.2), (1981, 22.8), (1982, 22.8), (1983, 24.5), (1984, 26.7), (1985, 27.3), (1986, 23.3), (1987, 23.7), (1988, 25.1), (1989, 30.0), (1990, 27.5), (1991, 40.0), (1992, 56.8), (1993, 69.4), (1994, 74.5), (1995, 74.9), (1996, 92.9), (1997, 98.0), (1998, 104), (1999, 119), (2000, 122), (2001, 125), (2002, 133), (2003, 141), (2004, 151), (2005, 134), (2006, 138), (2007, 139), (2008, 142), (2009, 148), (2010, 157)

Aquacultural_index[Alga,Aquacultural_N_content] = GRAPH(TIME)

(1980, 3.66), (1981, 3.66), (1982, 3.66), (1983, 3.66), (1984, 3.66), (1985, 3.66), (1986, 3.66), (1987, 3.66), (1988, 3.66), (1989, 3.66), (1990, 3.66), (1991, 3.66), (1992, 3.66), (1993, 3.66), (1994, 3.66), (1995, 3.66), (1996, 3.66), (1997, 3.66), (1998, 3.66), (1999, 3.66), (2000, 3.66), (2001, 3.66), (2002, 3.66), (2003, 3.66), (2004, 3.66), (2005, 3.66), (2006, 3.66), (2007, 3.66), (2008, 3.66), (2009, 3.66), (2010, 3.66)

Aquacultural_index[Others,Aq_production] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 10.0), (1991, 16.9), (1992, 29.6), (1993, 28.8), (1994, 31.9), (1995, 40.6), (1996, 51.9), (1997, 80.7), (1998, 86.3), (1999, 78.0), (2000, 79.9), (2001, 78.5), (2002, 89.7), (2003, 139), (2004, 210), (2005, 159), (2006, 167), (2007, 189), (2008, 161), (2009, 175), (2010, 190)

Aquacultural_index[Others,Aquacultural_N_content] = GRAPH(TIME)

(1980, 2.91), (1981, 2.91), (1982, 2.91), (1983, 2.91), (1984, 2.91), (1985, 2.91), (1986, 2.91), (1987, 2.91), (1988, 2.91), (1989, 2.91), (1990, 2.91), (1991, 2.91), (1992, 2.91), (1993, 2.91), (1994, 2.91), (1995, 2.91), (1996, 2.91), (1997, 2.91), (1998, 2.91), (1999, 2.91), (2000, 2.91), (2001, 2.91), (2002, 2.91), (2003, 2.91), (2004, 2.91), (2005, 2.91), (2006, 2.91), (2007, 2.91), (2008, 2.91), (2009, 2.91), (2010, 2.91)

Cultivated_ratio = GRAPH(TIME)

(1980, 0.3), (1981, 0.32), (1982, 0.33), (1983, 0.36), (1984, 0.4), (1985, 0.44), (1986, 0.46), (1987, 0.48), (1988, 0.5), (1989, 0.5), (1990, 0.49), (1991, 0.48), (1992, 0.5), (1993, 0.52), (1994, 0.53), (1995, 0.54), (1996, 0.57), (1997, 0.56), (1998, 0.56), (1999, 0.58), (2000, 0.6), (2001, 0.62), (2002, 0.64), (2003, 0.64), (2004, 0.65), (2005, 0.67), (2006, 0.68), (2007, 0.69), (2008, 0.7), (2009, 0.71), (2010, 0.71)

Atmosphere subsystem

Atmosphere(t) = Atmosphere(t - dt) + (ASIN - ASOUT) * dt

INIT Atmosphere = 0
INFLOWS:
ASIN = ASIN\N2O+ASIN\NH3+ASIN\NOx
OUTFLOWS:
ASOUT = ASOUT\Deposition+ASOUT\Export
ASIN\N2O = AQOUT\N2O + CLOUT\N2O + FROUT\N2O + GLOUT\N2O + SWOUT\N2O + UGOUT\N2O + WTOUT\N2O + IDOUT\N2O
ASIN\NH3 = AQOUT\NH3 + CLOUT\NH3 + ARRAYSUM(GLOUT\NH3[*]) + GLOUT\NH3\2 + HMOUT\NH3 + ARRAYSUM(LSOUT\NH3[*]) + UGOUT\NH3 + ASIN\NOx/2*46/17/100
ASIN\NOx = CLOUT\NO + GLOUT\Burning + GLOUT\NO + UGOUT\Burning + HMOUT\Burning + IDOUT\NOx + ARRAYSUM(CLOUT\Straw[*])*Straw_burning_ratio
ASOUT\Deposition = Deposition_rate*0.96
ASOUT\Export = ASIN-ASOUT\Deposition
Straw_burning_ratio = GRAPH(TIME)
(1980, 0.1), (1981, 0.11), (1982, 0.12), (1983, 0.12), (1984, 0.15), (1985, 0.16), (1986, 0.15), (1987, 0.18), (1988, 0.19), (1989, 0.2), (1990, 0.21), (1991, 0.23), (1992, 0.24), (1993, 0.25), (1994, 0.26), (1995, 0.27), (1996, 0.28), (1997, 0.26), (1998, 0.24), (1999, 0.22), (2000, 0.19), (2001, 0.23), (2002, 0.22), (2003, 0.22), (2004, 0.21), (2005, 0.2), (2006, 0.19), (2007, 0.18), (2008, 0.15), (2009, 0.17), (2010, 0.16)

Cropland subsystem
Cropland(t) = Cropland(t - dt) + (CLIN - CLOUT) * dt
INIT Cropland = 0
INFLOWS:
CLIN = CLIN\BNF+CLIN\Deposition+CLIN\Fertilizer+CLIN\Irrigation+CLIN\Manure+CLIN\Straw
OUTFLOWS:
CLOUT = CLOUT\Leaching+CLOUT\N2O+CLOUT\NH3+CLOUT\NO+CLOUT\Runoff+arraysum(CLOUT\Crop[*])+arraysum(CLOUT\Straw[*])+CLOUT\N2
CLAcc = CLIN-CLOUT
CLIN\BNF = (Sown_area[beans_area]*105+Sown_area[peanut_area]*112+Sown_area[greenfeed_area]*130+Sown_area[rice_area]*33+Sown_area[sugarcane_area]*25+Sown_area[other_area]*15)/10^6
CLIN\Deposition = Deposition_rate*ARRAYSUM(Cropland_area[*])/10^6
CLIN\Fertilizer = ARRAYSUM(Cropland_area[*])*Fertilization_rate/10^6
CLIN\Irrigation = Irrigation_water*water_N_con/10^4
CLIN\Manure = ARRAYSUM(HMOUT\Manure[*])+

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ARRAYSUM(LSOUT\Cropland[*])
CLIN\Straw = Arraysum(CLOUT\Straw[*])*Straw_recycled_ratio
CLOUT\Crop[Crop] =
Crop_index[Crop,Crop_production]*Crop_index[Crop,Crop_N_concentration]/10^4
CLOUT\Leaching = (CLIN\Fertilizer + CLIN\Irrigation +
CLIN\Deposition)*0.048+(CLIN\BNF + CLIN\Manure + CLIN\Straw)*0.04
CLOUT\N2 = (CLIN\Fertilizer + CLIN\Irrigation +
CLIN\Deposition)*0.162+(CLIN\BNF + CLIN\Manure + CLIN\Straw)*0.15
CLOUT\N2O = (CLIN\Fertilizer + CLIN\Irrigation +
CLIN\Deposition)*0.009+(CLIN\BNF + CLIN\Manure + CLIN\Straw)*0.01
CLOUT\NH3 =
(CLIN\Fertilizer+CLIN\Deposition)*0.178+ARRAYSUM(HMOUT\Manure[*])*0.23+A
RRAYSUM(LSOUT\NH3[*])*0.28
CLOUT\NO = (CLIN\Fertilizer + CLIN\Irrigation +
CLIN\Deposition)*0.005+(CLIN\BNF + CLIN\Manure + CLIN\Straw)*0.007
CLOUT\Runoff = (CLIN\Fertilizer + CLIN\Irrigation +
CLIN\Deposition)*0.055+(CLIN\BNF + CLIN\Manure + CLIN\Straw)*0.05
CLOUT\Straw[Crop] =
Crop_index[Crop,Crop_production]*Crop_index[Crop,Straw_grain_ratio]*Crop_index[C
rop,Straw_N_concentration]/10^4
Cropland_area[Upland] = GRAPH(TIME)
(1980, 100058), (1981, 99788), (1982, 99354), (1983, 99105), (1984, 98596), (1985, 97580),
(1986, 96960), (1987, 96616), (1988, 96448), (1989, 96381), (1990, 96398), (1991, 96379),
(1992, 96150), (1993, 95823), (1994, 95626), (1995, 95694), (1996, 95709), (1997, 95609),
(1998, 95417), (1999, 95095), (2000, 94387), (2001, 93925), (2002, 92684), (2003, 90817),
(2004, 90119), (2005, 88657), (2006, 87536), (2007, 89597), (2008, 89583), (2009, 89586),
(2010, 89586)
Cropland_area[Paddy_field] = GRAPH(TIME)
(1980, 35891), (1981, 35794), (1982, 35638), (1983, 35549), (1984, 35366), (1985, 35002),
(1986, 34779), (1987, 34656), (1988, 34595), (1989, 34572), (1990, 34578), (1991, 34571),
(1992, 34488), (1993, 34371), (1994, 34301), (1995, 34325), (1996, 34330), (1997, 34294),
(1998, 34226), (1999, 34110), (2000, 33856), (2001, 33691), (2002, 33245), (2003, 32576),
(2004, 32325), (2005, 31801), (2006, 31399), (2007, 32138), (2008, 32133), (2009, 32134),
(2010, 32134)
Crop_index[cereal,Crop_production] = GRAPH(TIME)
(1980, 27438), (1981, 27976), (1982, 30921), (1983, 33987), (1984, 36006), (1985, 33523),
(1986, 34870), (1987, 35495), (1988, 34754), (1989, 36396), (1990, 40114), (1991, 39566),
(1992, 40170), (1993, 40517), (1994, 39389), (1995, 41612), (1996, 45127), (1997, 44349),
(1998, 45625), (1999, 45304), (2000, 40522), (2001, 39648), (2002, 39799), (2003, 37429),
(2004, 41157), (2005, 42776), (2006, 45099), (2007, 45632), (2008, 47847), (2009, 48156),
(2010, 49637)
Crop_index[cereal,Straw_grain_ratio] = GRAPH(TIME)
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(1980, 1.07), (1981, 1.07), (1982, 1.07), (1983, 1.08), (1984, 1.08), (1985, 1.07), (1986, 1.07), (1987, 1.07), (1988, 1.07), (1989, 1.07), (1990, 1.07), (1991, 1.07), (1992, 1.07), (1993, 1.07), (1994, 1.07), (1995, 1.06), (1996, 1.07), (1997, 1.07), (1998, 1.06), (1999, 1.06), (2000, 1.06), (2001, 1.06), (2002, 1.06), (2003, 1.06), (2004, 1.06), (2005, 1.06), (2006, 1.06), (2007, 1.06), (2008, 1.06), (2009, 1.06), (2010, 1.06)

Crop_index[cereal,Crop_N_concentration] = GRAPH(TIME)

(1980, 1.48), (1981, 1.48), (1982, 1.48), (1983, 1.50), (1984, 1.50), (1985, 1.50), (1986, 1.51), (1987, 1.50), (1988, 1.51), (1989, 1.50), (1990, 1.51), (1991, 1.51), (1992, 1.52), (1993, 1.53), (1994, 1.53), (1995, 1.52), (1996, 1.53), (1997, 1.53), (1998, 1.52), (1999, 1.53), (2000, 1.51), (2001, 1.51), (2002, 1.51), (2003, 1.52), (2004, 1.51), (2005, 1.52), (2006, 1.54), (2007, 1.53), (2008, 1.53), (2009, 1.54), (2010, 1.54)

Crop_index[cereal,Straw_N_concentration] = GRAPH(TIME)

(1980, 0.66), (1981, 0.66), (1982, 0.66), (1983, 0.65), (1984, 0.65), (1985, 0.65), (1986, 0.65), (1987, 0.65), (1988, 0.65), (1989, 0.65), (1990, 0.65), (1991, 0.64), (1992, 0.64), (1993, 0.64), (1994, 0.64), (1995, 0.64), (1996, 0.64), (1997, 0.64), (1998, 0.64), (1999, 0.64), (2000, 0.64), (2001, 0.64), (2002, 0.64), (2003, 0.64), (2004, 0.64), (2005, 0.64), (2006, 0.63), (2007, 0.63), (2008, 0.63), (2009, 0.63), (2010, 0.63)

Crop_index[beans,Crop_production] = GRAPH(TIME)

(1980, 1042), (1981, 1224), (1982, 1185), (1983, 1281), (1984, 1273), (1985, 1378), (1986, 1524), (1987, 1636), (1988, 1529), (1989, 1342), (1990, 1444), (1991, 1247), (1992, 1252), (1993, 1950), (1994, 2096), (1995, 1788), (1996, 1790), (1997, 1876), (1998, 2001), (1999, 1894), (2000, 2010), (2001, 2053), (2002, 2241), (2003, 2128), (2004, 2232), (2005, 2158), (2006, 2004), (2007, 1720), (2008, 2043), (2009, 1930), (2010, 1897)

Crop_index[beans,Straw_grain_ratio] = GRAPH(TIME)

(1980, 1.30), (1981, 1.30), (1982, 1.30), (1983, 1.30), (1984, 1.30), (1985, 1.30), (1986, 1.30), (1987, 1.30), (1988, 1.30), (1989, 1.30), (1990, 1.30), (1991, 1.30), (1992, 1.30), (1993, 1.30), (1994, 1.30), (1995, 1.30), (1996, 1.30), (1997, 1.30), (1998, 1.30), (1999, 1.30), (2000, 1.30), (2001, 1.30), (2002, 1.30), (2003, 1.30), (2004, 1.30), (2005, 1.30), (2006, 1.30), (2007, 1.30), (2008, 1.30), (2009, 1.30), (2010, 1.30)

Crop_index[beans,Crop_N_concentration] = GRAPH(TIME)

(1980, 5.99), (1981, 5.99), (1982, 5.99), (1983, 5.99), (1984, 5.99), (1985, 5.99), (1986, 5.99), (1987, 5.99), (1988, 5.99), (1989, 5.99), (1990, 5.99), (1991, 5.99), (1992, 5.99), (1993, 5.99), (1994, 5.99), (1995, 5.99), (1996, 5.99), (1997, 5.99), (1998, 5.99), (1999, 5.99), (2000, 5.99), (2001, 5.99), (2002, 5.99), (2003, 5.99), (2004, 5.99), (2005, 5.99), (2006, 5.99), (2007, 5.99), (2008, 5.99), (2009, 5.99), (2010, 5.99)

Crop_index[beans,Straw_N_concentration] = GRAPH(TIME)

(1980, 1.93), (1981, 1.93), (1982, 1.93), (1983, 1.93), (1984, 1.93), (1985, 1.93), (1986, 1.93), (1987, 1.93), (1988, 1.93), (1989, 1.93), (1990, 1.93), (1991, 1.93), (1992, 1.93), (1993, 1.93), (1994, 1.93), (1995, 1.93), (1996, 1.93), (1997, 1.93), (1998, 1.93), (1999, 1.93), (2000, 1.93), (2001, 1.93), (2002, 1.93), (2003, 1.93), (2004, 1.93), (2005, 1.93), (2006, 1.93), (2007, 1.93), (2008, 1.93), (2009, 1.93), (2010, 1.93)

Crop_index[potatos,Crop_production] = GRAPH(TIME)

(1980, 2873), (1981, 2597), (1982, 2705), (1983, 2925), (1984, 2848), (1985, 2604), (1986, 2534), (1987, 2821), (1988, 2697), (1989, 2730), (1990, 2743), (1991, 2716), (1992, 2844), (1993, 3181), (1994, 3025), (1995, 3263), (1996, 3536), (1997, 3192), (1998, 3604), (1999, 3641), (2000, 3685), (2001, 3563), (2002, 3666), (2003, 3513), (2004, 3558), (2005, 3469), (2006, 2701), (2007, 2808), (2008, 2980), (2009, 2995), (2010, 3114)

Crop_index[potatos,Straw_grain_ratio] = GRAPH(TIME)

(1980, 0.5), (1981, 0.5), (1982, 0.5), (1983, 0.5), (1984, 0.5), (1985, 0.5), (1986, 0.5), (1987, 0.5), (1988, 0.5), (1989, 0.5), (1990, 0.5), (1991, 0.5), (1992, 0.5), (1993, 0.5), (1994, 0.5), (1995, 0.5), (1996, 0.5), (1997, 0.5), (1998, 0.5), (1999, 0.5), (2000, 0.5), (2001, 0.5), (2002, 0.5), (2003, 0.5), (2004, 0.5), (2005, 0.5), (2006, 0.5), (2007, 0.5), (2008, 0.5), (2009, 0.5), (2010, 0.5)

Crop_index[potatos,Crop_N_concentration] = GRAPH(TIME)

(1980, 0.26), (1981, 0.26), (1982, 0.26), (1983, 0.26), (1984, 0.26), (1985, 0.26), (1986, 0.26), (1987, 0.26), (1988, 0.26), (1989, 0.26), (1990, 0.26), (1991, 0.26), (1992, 0.26), (1993, 0.26), (1994, 0.26), (1995, 0.26), (1996, 0.26), (1997, 0.26), (1998, 0.26), (1999, 0.26), (2000, 0.26), (2001, 0.26), (2002, 0.26), (2003, 0.26), (2004, 0.26), (2005, 0.26), (2006, 0.26), (2007, 0.26), (2008, 0.26), (2009, 0.26), (2010, 0.26)

Crop_index[potatos,Straw_N_concentration] = GRAPH(TIME)

(1980, 3.00), (1981, 3.00), (1982, 3.00), (1983, 3.00), (1984, 3.00), (1985, 3.00), (1986, 3.00), (1987, 3.00), (1988, 3.00), (1989, 3.00), (1990, 3.00), (1991, 3.00), (1992, 3.00), (1993, 3.00), (1994, 3.00), (1995, 3.00), (1996, 3.00), (1997, 3.00), (1998, 3.00), (1999, 3.00), (2000, 3.00), (2001, 3.00), (2002, 3.00), (2003, 3.00), (2004, 3.00), (2005, 3.00), (2006, 3.00), (2007, 3.00), (2008, 3.00), (2009, 3.00), (2010, 3.00)

Crop_index[oilcrops,Crop_production] = GRAPH(TIME)

(1980, 769), (1981, 1021), (1982, 1182), (1983, 1055), (1984, 1191), (1985, 1578), (1986, 1474), (1987, 1528), (1988, 1320), (1989, 1295), (1990, 1613), (1991, 1638), (1992, 1641), (1993, 1804), (1994, 1990), (1995, 2250), (1996, 2211), (1997, 2157), (1998, 2314), (1999, 2601), (2000, 2955), (2001, 2865), (2002, 2897), (2003, 2811), (2004, 3066), (2005, 3077), (2006, 2640), (2007, 2569), (2008, 2946), (2009, 3154), (2010, 3230)

Crop_index[oilcrops,Straw_grain_ratio] = GRAPH(TIME)

(1980, 2.16), (1981, 2.38), (1982, 2.40), (1983, 2.32), (1984, 2.27), (1985, 2.28), (1986, 2.32), (1987, 2.32), (1988, 2.24), (1989, 2.27), (1990, 2.30), (1991, 2.32), (1992, 2.37), (1993, 2.21), (1994, 2.18), (1995, 2.24), (1996, 2.23), (1997, 2.26), (1998, 2.14), (1999, 2.19), (2000, 2.18), (2001, 2.18), (2002, 2.16), (2003, 2.19), (2004, 2.22), (2005, 2.21), (2006, 2.20), (2007, 2.17), (2008, 2.18), (2009, 2.21), (2010, 2.17)

Crop_index[oilcrops,Crop_N_concentration] = GRAPH(TIME)

(1980, 3.80), (1981, 3.80), (1982, 3.80), (1983, 3.80), (1984, 3.80), (1985, 3.80), (1986, 3.80), (1987, 3.80), (1988, 3.80), (1989, 3.80), (1990, 3.80), (1991, 3.80), (1992, 3.80), (1993, 3.80), (1994, 3.80), (1995, 3.80), (1996, 3.80), (1997, 3.80), (1998, 3.80), (1999, 3.80), (2000, 3.80), (2001, 3.80), (2002, 3.80), (2003, 3.80), (2004, 3.80), (2005, 3.80), (2006, 3.80), (2007, 3.80), (2008, 3.80), (2009, 3.80), (2010, 3.80)

Crop_index[oilcrops,Straw_N_concentration] = GRAPH(TIME)

(1980, 1.02), (1981, 1.02), (1982, 1.02), (1983, 1.02), (1984, 1.02), (1985, 1.02), (1986, 1.02),

(1987, 1.02), (1988, 1.02), (1989, 1.02), (1990, 1.02), (1991, 1.02), (1992, 1.02), (1993, 1.02), (1994, 1.02), (1995, 1.02), (1996, 1.02), (1997, 1.02), (1998, 1.02), (1999, 1.02), (2000, 1.02), (2001, 1.02), (2002, 1.02), (2003, 1.02), (2004, 1.02), (2005, 1.02), (2006, 1.02), (2007, 1.02), (2008, 1.02), (2009, 1.02), (2010, 1.02)

Crop_index[sugarcrop,Crop_production] = GRAPH(TIME)

(1980, 2911), (1981, 3603), (1982, 4359), (1983, 4032), (1984, 4780), (1985, 6047), (1986, 5853), (1987, 5550), (1988, 6187), (1989, 5804), (1990, 7214), (1991, 8419), (1992, 8808), (1993, 7624), (1994, 7345), (1995, 7940), (1996, 8360), (1997, 9386), (1998, 9790), (1999, 8334), (2000, 7635), (2001, 8655), (2002, 10293), (2003, 9642), (2004, 9571), (2005, 9452), (2006, 10460), (2007, 12188), (2008, 13420), (2009, 12277), (2010, 12008)

Crop_index[sugarcrop,Straw_grain_ratio] = GRAPH(TIME)

(1980, 0.1), (1981, 0.1), (1982, 0.1), (1983, 0.1), (1984, 0.1), (1985, 0.1), (1986, 0.1), (1987, 0.1), (1988, 0.1), (1989, 0.1), (1990, 0.1), (1991, 0.1), (1992, 0.1), (1993, 0.1), (1994, 0.1), (1995, 0.1), (1996, 0.1), (1997, 0.1), (1998, 0.1), (1999, 0.1), (2000, 0.1), (2001, 0.1), (2002, 0.1), (2003, 0.1), (2004, 0.1), (2005, 0.1), (2006, 0.1), (2007, 0.1), (2008, 0.1), (2009, 0.1), (2010, 0.1)

Crop_index[sugarcrop,Crop_N_concentration] = GRAPH(TIME)

(1980, 0.54), (1981, 0.54), (1982, 0.54), (1983, 0.54), (1984, 0.54), (1985, 0.54), (1986, 0.54), (1987, 0.54), (1988, 0.54), (1989, 0.54), (1990, 0.54), (1991, 0.54), (1992, 0.54), (1993, 0.54), (1994, 0.54), (1995, 0.54), (1996, 0.54), (1997, 0.54), (1998, 0.54), (1999, 0.54), (2000, 0.54), (2001, 0.54), (2002, 0.54), (2003, 0.54), (2004, 0.54), (2005, 0.54), (2006, 0.54), (2007, 0.54), (2008, 0.54), (2009, 0.54), (2010, 0.54)

Crop_index[sugarcrop,Straw_N_concentration] = GRAPH(TIME)

(1980, 0.67), (1981, 0.67), (1982, 0.67), (1983, 0.67), (1984, 0.67), (1985, 0.67), (1986, 0.67), (1987, 0.67), (1988, 0.67), (1989, 0.67), (1990, 0.67), (1991, 0.67), (1992, 0.67), (1993, 0.67), (1994, 0.67), (1995, 0.67), (1996, 0.67), (1997, 0.67), (1998, 0.67), (1999, 0.67), (2000, 0.67), (2001, 0.67), (2002, 0.67), (2003, 0.67), (2004, 0.67), (2005, 0.67), (2006, 0.67), (2007, 0.67), (2008, 0.67), (2009, 0.67), (2010, 0.67)

Crop_index[furits,Crop_production] = GRAPH(TIME)

(1980, 1304), (1981, 1509), (1982, 1500), (1983, 1776), (1984, 1910), (1985, 2612), (1986, 2857), (1987, 3348), (1988, 3394), (1989, 3341), (1990, 3177), (1991, 3539), (1992, 4168), (1993, 5080), (1994, 5581), (1995, 6469), (1996, 11589), (1997, 12875), (1998, 15678), (1999, 17164), (2000, 12489), (2001, 20345), (2002, 21797), (2003, 21483), (2004, 22288), (2005, 23405), (2006, 24605), (2007, 25752), (2008, 27101), (2009, 28545), (2010, 29938)

Crop_index[furits,Straw_grain_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Crop_index[furits,Crop_N_concentration] = GRAPH(TIME)

(1980, 0.12), (1981, 0.12), (1982, 0.12), (1983, 0.12), (1984, 0.12), (1985, 0.12), (1986, 0.12), (1987, 0.12), (1988, 0.12), (1989, 0.12), (1990, 0.12), (1991, 0.12), (1992, 0.12), (1993, 0.12),

(1994, 0.12), (1995, 0.12), (1996, 0.12), (1997, 0.12), (1998, 0.12), (1999, 0.12), (2000, 0.12), (2001, 0.12), (2002, 0.12), (2003, 0.12), (2004, 0.12), (2005, 0.12), (2006, 0.12), (2007, 0.12), (2008, 0.12), (2009, 0.12), (2010, 0.12)

Crop_index[furits,Straw_N_concentration] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Crop_index[vegetable,Crop_production] = GRAPH(TIME)

(1980, 9274), (1981, 10060), (1982, 10785), (1983, 12109), (1984, 13326), (1985, 13335), (1986, 15248), (1987, 15918), (1988, 17602), (1989, 18012), (1990, 18829), (1991, 18847), (1992, 21399), (1993, 25269), (1994, 27074), (1995, 25727), (1996, 30123), (1997, 35962), (1998, 38492), (1999, 40514), (2000, 46112), (2001, 48422), (2002, 52861), (2003, 54032), (2004, 55065), (2005, 56451), (2006, 53953), (2007, 56452), (2008, 59240), (2009, 61824), (2010, 65099)

Crop_index[vegetable,Straw_grain_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Crop_index[vegetable,Crop_N_concentration] = GRAPH(TIME)

(1980, 0.24), (1981, 0.24), (1982, 0.24), (1983, 0.24), (1984, 0.24), (1985, 0.24), (1986, 0.24), (1987, 0.24), (1988, 0.24), (1989, 0.24), (1990, 0.24), (1991, 0.24), (1992, 0.24), (1993, 0.24), (1994, 0.24), (1995, 0.24), (1996, 0.24), (1997, 0.24), (1998, 0.24), (1999, 0.24), (2000, 0.24), (2001, 0.24), (2002, 0.24), (2003, 0.24), (2004, 0.24), (2005, 0.24), (2006, 0.24), (2007, 0.24), (2008, 0.24), (2009, 0.24), (2010, 0.24)

Crop_index[vegetable,Straw_N_concentration] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Crop_index[tea,Crop_production] = GRAPH(TIME)

(1980, 30.4), (1981, 34.3), (1982, 39.7), (1983, 40.1), (1984, 41.4), (1985, 43.2), (1986, 46.0), (1987, 50.8), (1988, 54.5), (1989, 53.5), (1990, 54.0), (1991, 54.2), (1992, 56.0), (1993, 60.0), (1994, 58.9), (1995, 58.8), (1996, 59.3), (1997, 61.3), (1998, 66.5), (1999, 67.6), (2000, 68.3), (2001, 70.2), (2002, 74.5), (2003, 76.8), (2004, 83.5), (2005, 93.5), (2006, 103), (2007, 117), (2008, 126), (2009, 136), (2010, 148)

Crop_index[tea,Straw_grain_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00),

(1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Crop_index[tea,Crop_N_concentration] = GRAPH(TIME)

(1980, 3.50), (1981, 3.50), (1982, 3.50), (1983, 3.50), (1984, 3.50), (1985, 3.50), (1986, 3.50), (1987, 3.50), (1988, 3.50), (1989, 3.50), (1990, 3.50), (1991, 3.50), (1992, 3.50), (1993, 3.50), (1994, 3.50), (1995, 3.50), (1996, 3.50), (1997, 3.50), (1998, 3.50), (1999, 3.50), (2000, 3.50), (2001, 3.50), (2002, 3.50), (2003, 3.50), (2004, 3.50), (2005, 3.50), (2006, 3.50), (2007, 3.50), (2008, 3.50), (2009, 3.50), (2010, 3.50)

Crop_index[tea,Straw_N_concentration] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Crop_index[cotton,Crop_production] = GRAPH(TIME)

(1980, 271), (1981, 297), (1982, 360), (1983, 464), (1984, 626), (1985, 415), (1986, 354), (1987, 425), (1988, 415), (1989, 379), (1990, 451), (1991, 568), (1992, 451), (1993, 374), (1994, 434), (1995, 477), (1996, 420), (1997, 460), (1998, 450), (1999, 383), (2000, 442), (2001, 532), (2002, 492), (2003, 486), (2004, 632), (2005, 571), (2006, 753), (2007, 762), (2008, 749), (2009, 638), (2010, 596)

Crop_index[cotton,Straw_grain_ratio] = GRAPH(TIME)

(1980, 1.61), (1981, 1.61), (1982, 1.61), (1983, 1.61), (1984, 1.61), (1985, 1.61), (1986, 1.61), (1987, 1.61), (1988, 1.61), (1989, 1.61), (1990, 1.61), (1991, 1.61), (1992, 1.61), (1993, 1.61), (1994, 1.61), (1995, 1.61), (1996, 1.61), (1997, 1.61), (1998, 1.61), (1999, 1.61), (2000, 1.61), (2001, 1.61), (2002, 1.61), (2003, 1.61), (2004, 1.61), (2005, 1.61), (2006, 1.61), (2007, 1.61), (2008, 1.61), (2009, 1.61), (2010, 1.61)

Crop_index[cotton,Crop_N_concentration] = GRAPH(TIME)

(1980, 0.21), (1981, 0.21), (1982, 0.21), (1983, 0.21), (1984, 0.21), (1985, 0.21), (1986, 0.21), (1987, 0.21), (1988, 0.21), (1989, 0.21), (1990, 0.21), (1991, 0.21), (1992, 0.21), (1993, 0.21), (1994, 0.21), (1995, 0.21), (1996, 0.21), (1997, 0.21), (1998, 0.21), (1999, 0.21), (2000, 0.21), (2001, 0.21), (2002, 0.21), (2003, 0.21), (2004, 0.21), (2005, 0.21), (2006, 0.21), (2007, 0.21), (2008, 0.21), (2009, 0.21), (2010, 0.21)

Crop_index[cotton,Straw_N_concentration] = GRAPH(TIME)

(1980, 1.59), (1981, 1.59), (1982, 1.59), (1983, 1.59), (1984, 1.59), (1985, 1.59), (1986, 1.59), (1987, 1.59), (1988, 1.59), (1989, 1.59), (1990, 1.59), (1991, 1.59), (1992, 1.59), (1993, 1.59), (1994, 1.59), (1995, 1.59), (1996, 1.59), (1997, 1.59), (1998, 1.59), (1999, 1.59), (2000, 1.59), (2001, 1.59), (2002, 1.59), (2003, 1.59), (2004, 1.59), (2005, 1.59), (2006, 1.59), (2007, 1.59), (2008, 1.59), (2009, 1.59), (2010, 1.59)

Crop_index[hemp,Crop_production] = GRAPH(TIME)

(1980, 144), (1981, 158), (1982, 124), (1983, 125), (1984, 179), (1985, 445), (1986, 193), (1987,

208), (1988, 181), (1989, 112), (1990, 110), (1991, 88.5), (1992, 93.8), (1993, 96.0), (1994, 74.7), (1995, 89.7), (1996, 79.5), (1997, 74.9), (1998, 49.5), (1999, 47.2), (2000, 53.0), (2001, 68.1), (2002, 96.4), (2003, 85.3), (2004, 107), (2005, 110), (2006, 89.1), (2007, 72.8), (2008, 62.5), (2009, 38.8), (2010, 31.8)

Crop_index[hemp,Straw_grain_ratio] = GRAPH(TIME)

(1980, 1.81), (1981, 1.81), (1982, 1.81), (1983, 1.81), (1984, 1.81), (1985, 1.81), (1986, 1.81), (1987, 1.81), (1988, 1.81), (1989, 1.81), (1990, 1.81), (1991, 1.81), (1992, 1.81), (1993, 1.81), (1994, 1.81), (1995, 1.81), (1996, 1.81), (1997, 1.81), (1998, 1.81), (1999, 1.81), (2000, 1.81), (2001, 1.81), (2002, 1.81), (2003, 1.81), (2004, 1.81), (2005, 1.81), (2006, 1.81), (2007, 1.81), (2008, 1.81), (2009, 1.81), (2010, 1.81)

Crop_index[hemp,Crop_N_concentration] = GRAPH(TIME)

(1980, 0.75), (1981, 0.75), (1982, 0.75), (1983, 0.75), (1984, 0.75), (1985, 0.75), (1986, 0.75), (1987, 0.75), (1988, 0.75), (1989, 0.75), (1990, 0.75), (1991, 0.75), (1992, 0.75), (1993, 0.75), (1994, 0.75), (1995, 0.75), (1996, 0.75), (1997, 0.75), (1998, 0.75), (1999, 0.75), (2000, 0.75), (2001, 0.75), (2002, 0.75), (2003, 0.75), (2004, 0.75), (2005, 0.75), (2006, 0.75), (2007, 0.75), (2008, 0.75), (2009, 0.75), (2010, 0.75)

Crop_index[hemp,Straw_N_concentration] = GRAPH(TIME)

(1980, 0.34), (1981, 0.34), (1982, 0.34), (1983, 0.34), (1984, 0.34), (1985, 0.34), (1986, 0.34), (1987, 0.34), (1988, 0.34), (1989, 0.34), (1990, 0.34), (1991, 0.34), (1992, 0.34), (1993, 0.34), (1994, 0.34), (1995, 0.34), (1996, 0.34), (1997, 0.34), (1998, 0.34), (1999, 0.34), (2000, 0.34), (2001, 0.34), (2002, 0.34), (2003, 0.34), (2004, 0.34), (2005, 0.34), (2006, 0.34), (2007, 0.34), (2008, 0.34), (2009, 0.34), (2010, 0.34)

Crop_index[tobacco,Crop_production] = GRAPH(TIME)

(1980, 84.5), (1981, 150), (1982, 218), (1983, 138), (1984, 179), (1985, 242), (1986, 171), (1987, 194), (1988, 273), (1989, 283), (1990, 263), (1991, 303), (1992, 350), (1993, 345), (1994, 224), (1995, 231), (1996, 323), (1997, 425), (1998, 236), (1999, 247), (2000, 255), (2001, 235), (2002, 245), (2003, 226), (2004, 241), (2005, 268), (2006, 246), (2007, 240), (2008, 284), (2009, 307), (2010, 300)

Crop_index[tobacco,Straw_grain_ratio] = GRAPH(TIME)

(1980, 1.06), (1981, 1.06), (1982, 1.06), (1983, 1.06), (1984, 1.06), (1985, 1.06), (1986, 1.06), (1987, 1.06), (1988, 1.06), (1989, 1.06), (1990, 1.06), (1991, 1.06), (1992, 1.06), (1993, 1.06), (1994, 1.06), (1995, 1.06), (1996, 1.06), (1997, 1.06), (1998, 1.06), (1999, 1.06), (2000, 1.06), (2001, 1.06), (2002, 1.06), (2003, 1.06), (2004, 1.06), (2005, 1.06), (2006, 1.06), (2007, 1.06), (2008, 1.06), (2009, 1.06), (2010, 1.06)

Crop_index[tobacco,Crop_N_concentration] = GRAPH(TIME)

(1980, 1.53), (1981, 1.53), (1982, 1.53), (1983, 1.53), (1984, 1.53), (1985, 1.53), (1986, 1.53), (1987, 1.53), (1988, 1.53), (1989, 1.53), (1990, 1.53), (1991, 1.53), (1992, 1.53), (1993, 1.53), (1994, 1.53), (1995, 1.53), (1996, 1.53), (1997, 1.53), (1998, 1.53), (1999, 1.53), (2000, 1.53), (2001, 1.53), (2002, 1.53), (2003, 1.53), (2004, 1.53), (2005, 1.53), (2006, 1.53), (2007, 1.53), (2008, 1.53), (2009, 1.53), (2010, 1.53)

Crop_index[tobacco,Straw_N_concentration] = GRAPH(TIME)

(1980, 0.75), (1981, 0.75), (1982, 0.75), (1983, 0.75), (1984, 0.75), (1985, 0.75), (1986, 0.75),

(1987, 0.75), (1988, 0.75), (1989, 0.75), (1990, 0.75), (1991, 0.75), (1992, 0.75), (1993, 0.75), (1994, 0.75), (1995, 0.75), (1996, 0.75), (1997, 0.75), (1998, 0.75), (1999, 0.75), (2000, 0.75), (2001, 0.75), (2002, 0.75), (2003, 0.75), (2004, 0.75), (2005, 0.75), (2006, 0.75), (2007, 0.75), (2008, 0.75), (2009, 0.75), (2010, 0.75)

Deposition_rate = GRAPH(TIME)

(1980, 7.75), (1981, 8.06), (1982, 8.36), (1983, 8.67), (1984, 8.98), (1985, 9.11), (1986, 9.67), (1987, 10.2), (1988, 10.8), (1989, 11.3), (1990, 11.9), (1991, 12.5), (1992, 12.9), (1993, 13.7), (1994, 14.2), (1995, 15.1), (1996, 15.6), (1997, 15.6), (1998, 16.1), (1999, 16.5), (2000, 16.5), (2001, 16.5), (2002, 16.7), (2003, 17.4), (2004, 18.3), (2005, 19.1), (2006, 19.7), (2007, 20.3), (2008, 20.8), (2009, 21.3), (2010, 21.8)

Fertilization_rate = GRAPH(TIME)

(1980, 69.3), (1981, 75.6), (1982, 81.6), (1983, 88.3), (1984, 93.5), (1985, 94.9), (1986, 104), (1987, 106), (1988, 114), (1989, 124), (1990, 133), (1991, 141), (1992, 145), (1993, 153), (1994, 159), (1995, 171), (1996, 182), (1997, 186), (1998, 191), (1999, 189), (2000, 190), (2001, 193), (2002, 196), (2003, 201), (2004, 211), (2005, 218), (2006, 225), (2007, 226), (2008, 229), (2009, 233), (2010, 238)

Irrigation_water = GRAPH(TIME)

(1980, 2693), (1981, 2674), (1982, 2651), (1983, 2679), (1984, 2667), (1985, 2642), (1986, 2654), (1987, 2664), (1988, 2663), (1989, 2695), (1990, 2844), (1991, 2869), (1992, 2915), (1993, 2924), (1994, 2926), (1995, 2957), (1996, 3023), (1997, 3074), (1998, 3138), (1999, 3190), (2000, 3229), (2001, 3255), (2002, 3261), (2003, 3241), (2004, 3269), (2005, 3302), (2006, 3345), (2007, 3391), (2008, 3508), (2009, 3556), (2010, 3621)

Sown_area[beans_area] = GRAPH(TIME)

(1980, 9765), (1981, 10842), (1982, 11376), (1983, 10225), (1984, 9846), (1985, 10429), (1986, 11208), (1987, 11412), (1988, 10972), (1989, 10888), (1990, 10215), (1991, 9163), (1992, 8983), (1993, 12377), (1994, 12736), (1995, 11232), (1996, 10543), (1997, 11164), (1998, 11671), (1999, 11189), (2000, 12660), (2001, 13268), (2002, 12543), (2003, 12899), (2004, 12799), (2005, 12901), (2006, 12149), (2007, 11780), (2008, 12118), (2009, 11949), (2010, 11276)

Sown_area[peanut_area] = GRAPH(TIME)

(1980, 2339), (1981, 2472), (1982, 2416), (1983, 2201), (1984, 2421), (1985, 3318), (1986, 3253), (1987, 3022), (1988, 2977), (1989, 2946), (1990, 2907), (1991, 2880), (1992, 2976), (1993, 3379), (1994, 3776), (1995, 3809), (1996, 3616), (1997, 3722), (1998, 4039), (1999, 4268), (2000, 4856), (2001, 4991), (2002, 4921), (2003, 5057), (2004, 4745), (2005, 4662), (2006, 3956), (2007, 3945), (2008, 4246), (2009, 4377), (2010, 4527)

Sown_area[greenfeed_area] = GRAPH(TIME)

(1980, 1786), (1981, 1685), (1982, 1647), (1983, 1622), (1984, 1605), (1985, 1665), (1986, 1739), (1987, 1842), (1988, 1856), (1989, 1885), (1990, 1862), (1991, 1837), (1992, 1787), (1993, 2007), (1994, 2228), (1995, 1825), (1996, 1807), (1997, 1818), (1998, 1862), (1999, 1849), (2000, 2142), (2001, 2590), (2002, 3014), (2003, 3548), (2004, 3349), (2005, 3376), (2006, 2898), (2007, 2824), (2008, 2296), (2009, 2069), (2010, 1882)

Sown_area[rice_area] = GRAPH(TIME)

(1980, 33878), (1981, 33295), (1982, 33071), (1983, 33136), (1984, 33178), (1985, 32070),

(1986, 32266), (1987, 32193), (1988, 31987), (1989, 32700), (1990, 33064), (1991, 32590), (1992, 32090), (1993, 30355), (1994, 30171), (1995, 30744), (1996, 31406), (1997, 31765), (1998, 31214), (1999, 31283), (2000, 29962), (2001, 28812), (2002, 28202), (2003, 26508), (2004, 28379), (2005, 28847), (2006, 28938), (2007, 28919), (2008, 29241), (2009, 29627), (2010, 29873)

Sown_area[sugarcane_area] = GRAPH(TIME)

(1980, 480), (1981, 551), (1982, 653), (1983, 654), (1984, 728), (1985, 965), (1986, 950), (1987, 859), (1988, 924), (1989, 959), (1990, 1009), (1991, 1164), (1992, 1246), (1993, 1088), (1994, 1057), (1995, 1125), (1996, 1207), (1997, 1311), (1998, 1401), (1999, 1303), (2000, 1185), (2001, 1248), (2002, 1393), (2003, 1409), (2004, 1378), (2005, 1354), (2006, 1378), (2007, 1586), (2008, 1743), (2009, 1697), (2010, 1686)

Sown_area[other_area] = GRAPH(TIME)

(1980, 98132), (1981, 96312), (1982, 95590), (1983, 96154), (1984, 96443), (1985, 95179), (1986, 94788), (1987, 95629), (1988, 96153), (1989, 97175), (1990, 99304), (1991, 101952), (1992, 101925), (1993, 98534), (1994, 98273), (1995, 101144), (1996, 103802), (1997, 104190), (1998, 105519), (1999, 106480), (2000, 105496), (2001, 104798), (2002, 104563), (2003, 102994), (2004, 102903), (2005, 104346), (2006, 102831), (2007, 104411), (2008, 106621), (2009, 108895), (2010, 111430)

Straw_recycled_ratio = GRAPH(TIME)

(1980, 0.07), (1981, 0.08), (1982, 0.09), (1983, 0.09), (1984, 0.1), (1985, 0.11), (1986, 0.11), (1987, 0.12), (1988, 0.12), (1989, 0.13), (1990, 0.13), (1991, 0.13), (1992, 0.14), (1993, 0.14), (1994, 0.15), (1995, 0.15), (1996, 0.12), (1997, 0.12), (1998, 0.16), (1999, 0.19), (2000, 0.22), (2001, 0.18), (2002, 0.19), (2003, 0.16), (2004, 0.22), (2005, 0.23), (2006, 0.24), (2007, 0.25), (2008, 0.27), (2009, 0.27), (2010, 0.28)

water_N_con = GRAPH(TIME)

(1980, 0.19), (1981, 0.26), (1982, 0.32), (1983, 0.39), (1984, 0.45), (1985, 0.52), (1986, 0.58), (1987, 0.65), (1988, 0.71), (1989, 0.78), (1990, 0.84), (1991, 0.91), (1992, 0.97), (1993, 1.04), (1994, 1.10), (1995, 1.17), (1996, 1.23), (1997, 1.30), (1998, 1.36), (1999, 1.43), (2000, 1.49), (2001, 1.56), (2002, 1.62), (2003, 1.69), (2004, 1.75), (2005, 1.70), (2006, 1.65), (2007, 1.60), (2008, 1.50), (2009, 1.50), (2010, 1.60)

Forest subsystem

Forest(t) = Forest(t - dt) + (FRIN - FROUT) * dt

INIT Forest = 0

INFLOWS:

FRIN = arraysum(FRIN\BNF[*])+FRIN\Deposition

OUTFLOWS:

FROUT = FROUT\N2+FROUT\N2O+FROUT\Runoff+FROUT\Wood

FRAcc = FRIN*0.5

FRIN\BNF[Forest1] = Forest_area[Forest1,Area]*Forest_area[Forest1,BNF_rate]/10^5

FRIN\Deposition = Deposition_rate*arraysum(Forest_area[*,Area])/10^5

FROUT\N2 = FRIN-FRAcc-FROUT\N2O-FROUT\Runoff-FROUT\Wood

FROUT\N2O = FRIN*0.05
FROUT\Runoff = FRIN\Deposition*0.22
FROUT\Wood = Wood_production*0.0019/100
Forest_area[Evergreen,Area] = GRAPH(TIME)
(1980, 2790), (1981, 2804), (1982, 2818), (1983, 2832), (1984, 2845), (1985, 2859), (1986, 2873), (1987, 2887), (1988, 2901), (1989, 2915), (1990, 2928), (1991, 2942), (1992, 2956), (1993, 2970), (1994, 2978), (1995, 2985), (1996, 2993), (1997, 3001), (1998, 3008), (1999, 3163), (2000, 3317), (2001, 3472), (2002, 3626), (2003, 3781), (2004, 3935), (2005, 3935), (2006, 3935), (2007, 3935), (2008, 3935), (2009, 3935), (2010, 3935)
Forest_area[Evergreen,BNF_rate] = GRAPH(TIME)
(1980, 17.0), (1981, 17.0), (1982, 17.0), (1983, 17.0), (1984, 17.0), (1985, 17.0), (1986, 17.0), (1987, 17.0), (1988, 17.0), (1989, 17.0), (1990, 17.0), (1991, 17.0), (1992, 17.0), (1993, 17.0), (1994, 17.0), (1995, 17.0), (1996, 17.0), (1997, 17.0), (1998, 17.0), (1999, 17.0), (2000, 17.0), (2001, 17.0), (2002, 17.0), (2003, 17.0), (2004, 17.0), (2005, 17.0), (2006, 17.0), (2007, 17.0), (2008, 17.0), (2009, 17.0), (2010, 17.0)
Forest_area[Evergreen,Wood_N_concen] = GRAPH(TIME)
(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)
Forest_area[Deciduous,Area] = GRAPH(TIME)
(1980, 2282), (1981, 2293), (1982, 2304), (1983, 2316), (1984, 2327), (1985, 2338), (1986, 2350), (1987, 2361), (1988, 2372), (1989, 2384), (1990, 2395), (1991, 2406), (1992, 2417), (1993, 2429), (1994, 2435), (1995, 2441), (1996, 2448), (1997, 2454), (1998, 2460), (1999, 2586), (2000, 2713), (2001, 2839), (2002, 2966), (2003, 3092), (2004, 3218), (2005, 3218), (2006, 3218), (2007, 3218), (2008, 3218), (2009, 3218), (2010, 3218)
Forest_area[Deciduous,BNF_rate] = GRAPH(TIME)
(1980, 8.50), (1981, 8.50), (1982, 8.50), (1983, 8.50), (1984, 8.50), (1985, 8.50), (1986, 8.50), (1987, 8.50), (1988, 8.50), (1989, 8.50), (1990, 8.50), (1991, 8.50), (1992, 8.50), (1993, 8.50), (1994, 8.50), (1995, 8.50), (1996, 8.50), (1997, 8.50), (1998, 8.50), (1999, 8.50), (2000, 8.50), (2001, 8.50), (2002, 8.50), (2003, 8.50), (2004, 8.50), (2005, 8.50), (2006, 8.50), (2007, 8.50), (2008, 8.50), (2009, 8.50), (2010, 8.50)
Forest_area[Deciduous,Wood_N_concen] = GRAPH(TIME)
(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)
Forest_area[Mixed,Area] = GRAPH(TIME)
(1980, 335), (1981, 336), (1982, 338), (1983, 340), (1984, 341), (1985, 343), (1986, 345), (1987, 346), (1988, 348), (1989, 350), (1990, 351), (1991, 353), (1992, 355), (1993, 356), (1994, 357),

(1995, 358), (1996, 359), (1997, 360), (1998, 361), (1999, 380), (2000, 398), (2001, 417), (2002, 435), (2003, 454), (2004, 472), (2005, 472), (2006, 472), (2007, 472), (2008, 472), (2009, 472), (2010, 472)

Forest_area[Mixed,BNF_rate] = GRAPH(TIME)

(1980, 7.48), (1981, 7.48), (1982, 7.48), (1983, 7.48), (1984, 7.48), (1985, 7.48), (1986, 7.48), (1987, 7.48), (1988, 7.48), (1989, 7.48), (1990, 7.48), (1991, 7.48), (1992, 7.48), (1993, 7.48), (1994, 7.48), (1995, 7.48), (1996, 7.48), (1997, 7.48), (1998, 7.48), (1999, 7.48), (2000, 7.48), (2001, 7.48), (2002, 7.48), (2003, 7.48), (2004, 7.48), (2005, 7.48), (2006, 7.48), (2007, 7.48), (2008, 7.48), (2009, 7.48), (2010, 7.48)

Forest_area[Mixed,Wood_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Forest_area[Coniferous,Area] = GRAPH(TIME)

(1980, 6994), (1981, 7028), (1982, 7063), (1983, 7098), (1984, 7132), (1985, 7167), (1986, 7202), (1987, 7237), (1988, 7271), (1989, 7306), (1990, 7341), (1991, 7375), (1992, 7410), (1993, 7445), (1994, 7464), (1995, 7483), (1996, 7502), (1997, 7522), (1998, 7541), (1999, 7928), (2000, 8315), (2001, 8703), (2002, 9090), (2003, 9478), (2004, 9865), (2005, 9865), (2006, 9865), (2007, 9865), (2008, 9865), (2009, 9865), (2010, 9865)

Forest_area[Coniferous,BNF_rate] = GRAPH(TIME)

(1980, 6.55), (1981, 6.55), (1982, 6.55), (1983, 6.55), (1984, 6.55), (1985, 6.55), (1986, 6.55), (1987, 6.55), (1988, 6.55), (1989, 6.55), (1990, 6.55), (1991, 6.55), (1992, 6.55), (1993, 6.55), (1994, 6.55), (1995, 6.55), (1996, 6.55), (1997, 6.55), (1998, 6.55), (1999, 6.55), (2000, 6.55), (2001, 6.55), (2002, 6.55), (2003, 6.55), (2004, 6.55), (2005, 6.55), (2006, 6.55), (2007, 6.55), (2008, 6.55), (2009, 6.55), (2010, 6.55)

Forest_area[Coniferous,Wood_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Forest_area[Shrub,Area] = GRAPH(TIME)

(1980, 21500), (1981, 21500), (1982, 21500), (1983, 21500), (1984, 21500), (1985, 21500), (1986, 21500), (1987, 21500), (1988, 21500), (1989, 21500), (1990, 21500), (1991, 21500), (1992, 21500), (1993, 21500), (1994, 21500), (1995, 21500), (1996, 21500), (1997, 21500), (1998, 21500), (1999, 21500), (2000, 21500), (2001, 21500), (2002, 21500), (2003, 21500), (2004, 21500), (2005, 21500), (2006, 21500), (2007, 21500), (2008, 21500), (2009, 21500), (2010, 21500)

Forest_area[Shrub,BNF_rate] = GRAPH(TIME)

(1980, 9.88), (1981, 9.88), (1982, 9.88), (1983, 9.88), (1984, 9.88), (1985, 9.88), (1986, 9.88),

(1987, 9.88), (1988, 9.88), (1989, 9.88), (1990, 9.88), (1991, 9.88), (1992, 9.88), (1993, 9.88), (1994, 9.88), (1995, 9.88), (1996, 9.88), (1997, 9.88), (1998, 9.88), (1999, 9.88), (2000, 9.88), (2001, 9.88), (2002, 9.88), (2003, 9.88), (2004, 9.88), (2005, 9.88), (2006, 9.88), (2007, 9.88), (2008, 9.88), (2009, 9.88), (2010, 9.88)

Forest_area[Shrub,Wood_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Forest_area[Bamboo,Area] = GRAPH(TIME)

(1980, 350), (1981, 350), (1982, 350), (1983, 350), (1984, 350), (1985, 350), (1986, 350), (1987, 350), (1988, 350), (1989, 350), (1990, 350), (1991, 350), (1992, 350), (1993, 350), (1994, 350), (1995, 350), (1996, 350), (1997, 350), (1998, 350), (1999, 350), (2000, 350), (2001, 350), (2002, 350), (2003, 350), (2004, 350), (2005, 350), (2006, 350), (2007, 350), (2008, 350), (2009, 350), (2010, 350)

Forest_area[Bamboo,BNF_rate] = GRAPH(TIME)

(1980, 9.88), (1981, 9.88), (1982, 9.88), (1983, 9.88), (1984, 9.88), (1985, 9.88), (1986, 9.88), (1987, 9.88), (1988, 9.88), (1989, 9.88), (1990, 9.88), (1991, 9.88), (1992, 9.88), (1993, 9.88), (1994, 9.88), (1995, 9.88), (1996, 9.88), (1997, 9.88), (1998, 9.88), (1999, 9.88), (2000, 9.88), (2001, 9.88), (2002, 9.88), (2003, 9.88), (2004, 9.88), (2005, 9.88), (2006, 9.88), (2007, 9.88), (2008, 9.88), (2009, 9.88), (2010, 9.88)

Forest_area[Bamboo,Wood_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Wood_production = GRAPH(TIME)

(1980, 12077), (1981, 12077), (1982, 12225), (1983, 12860), (1984, 15643), (1985, 15268), (1986, 15705), (1987, 15534), (1988, 14812), (1989, 13976), (1990, 13457), (1991, 14027), (1992, 14865), (1993, 15459), (1994, 15824), (1995, 16187), (1996, 16052), (1997, 15297), (1998, 14274), (1999, 12649), (2000, 11410), (2001, 10995), (2002, 10715), (2003, 11743), (2004, 12533), (2005, 13431), (2006, 15970), (2007, 16852), (2008, 19585), (2009, 17072), (2010, 19541)

Garbage treatment subsystem

Garbage__treatment(t) = Garbage__treatment(t - dt) + (GTIN - GTOUT) * dt

INIT Garbage__treatment = 0

INFLOWS:

GTIN =

GTIN\Domestic_burning+GTIN\Domestic_landfill+GTIN\Lawn_burning+GTIN\Lawn

_landfill+GTIN\Pet
OUTFLOWS:
GTOUT = GTOUT\Burning+GTOUT\Leakage
GTAcc = GTIN-GTOUT
GTIN\Domestic_burning = HMOUT\Burning - HMIN\Fuel- + HMIN\Straw
GTIN\Domestic_landfill = HMOUT\Landfill
GTIN\Lawn_burning = UGOUT\Burning
GTIN\Lawn_landfill = UGOUT\Landfill
GTIN\Pet = PTOUT\Landfill
GTOUT\Burning = GTIN\Domestic_burning+GTIN\Lawn_burning
GTOUT\Leakage = (GTIN-GTOUT\Burning)/6

Grassland subsystem
Grassland(t) = Grassland(t - dt) + (GLIN - GLOUT) * dt
INIT Grassland = 0
INFLOWS:
GLIN = GLIN\BNF+GLIN\Deposition+GLIN\Fertilizer
OUTFLOWS:
GLOUT =
GLOUT\Burning+ARRAYSUM(GLOUT\Food[*])+GLOUT\Leaching+ARRAYSUM(
GLOUT\Material[*])+GLOUT\N2+GLOUT\N2O+ARRAYSUM(GLOUT\NH3[*])+
GLOUT\NO+GLOUT\NH3\2
Forage = (NG_area*Forage_yield*0.842+AG_area*9950)*15/6.25*0.88/10^8
GLAcc = GLIN-GLOUT
GLIN\BNF = NG_area*3/10^6+Forage*0.2
GLIN\Deposition = Deposition_rate*(AG_area+NG_area)/10^6*0.65
GLIN\Fertilizer = AG_area*100/10^6
GLOUT\Burning = (ARRAYSUM(GL_Excretion[*])-
ARRAYSUM(GLOUT\NH3[*]))*Excretion_Burning_ratio
GLOUT\Food[Animal] =
Livestock_index[Animal,Livestock_production]*Livestock_index[Animal,Livestock_N_co
ncen]*Livestock_index[Animal,Livestock_grassland_ratio]/10^8
GLOUT\Leaching = (GLIN - ARRAYSUM(GLOUT\NH3[*]) +
ARRAYSUM(GL_Excretion[*])- GLIN\BNF)*0.05
GLOUT\Material[Animal] =
Livestock_index[Animal,Livestock_material_production]*Livestock_index[Animal,Livesto
ck_material_N_concen]*Livestock_index[Animal,Livestock_grassland_ratio]/10^8
GLOUT\N2 = (GLIN - ARRAYSUM(GLOUT\NH3[*]) +
ARRAYSUM(GL_Excretion[*]))*0.2
GLOUT\N2O = (GLIN - ARRAYSUM(GLOUT\NH3[*]) +
ARRAYSUM(GL_Excretion[*]))*0.025
GLOUT\NH3[Animal] =

Livestock_index[Animal,Livestock_numbers]*Livestock_index[Animal,Livestock_total_NH3]*Livestock_index[Animal,Livestock_grassland_ratio]/10^6

GLOUT\NH3\2 = (GLIN\Deposition+GLIN\Fertilizer)*0.21

GLOUT\NO = (GLIN - ARRAYSUM(GLOUT\NH3[*]) + ARRAYSUM(GL_Excretion[*]))*0.012

GL_Excretion[Animal] = Livestock_index[Animal,Livestock_numbers]*Livestock_index[Animal,Livestock_excretion]*Livestock_index[Animal,Livestock_grassland_ratio]/10^6

AG_area = GRAPH(TIME)

(1980, 6080), (1981, 6105), (1982, 6129), (1983, 6154), (1984, 6178), (1985, 6203), (1986, 6228), (1987, 6252), (1988, 6277), (1989, 6301), (1990, 6326), (1991, 6350), (1992, 6375), (1993, 6400), (1994, 6424), (1995, 6449), (1996, 6473), (1997, 6498), (1998, 6523), (1999, 6547), (2000, 6572), (2001, 6596), (2002, 6621), (2003, 6645), (2004, 6670), (2005, 6695), (2006, 6671), (2007, 6696), (2008, 6672), (2009, 6672), (2010, 6672)

Excretion_Burning_ratio = GRAPH(TIME)

(1980, 0.2), (1981, 0.2), (1982, 0.2), (1983, 0.19), (1984, 0.19), (1985, 0.19), (1986, 0.19), (1987, 0.19), (1988, 0.18), (1989, 0.18), (1990, 0.18), (1991, 0.18), (1992, 0.18), (1993, 0.17), (1994, 0.17), (1995, 0.17), (1996, 0.17), (1997, 0.16), (1998, 0.16), (1999, 0.16), (2000, 0.16), (2001, 0.16), (2002, 0.15), (2003, 0.15), (2004, 0.15), (2005, 0.15), (2006, 0.15), (2007, 0.14), (2008, 0.14), (2009, 0.14), (2010, 0.14)

Forage_yield = GRAPH(TIME)

(1980, 946), (1981, 944), (1982, 878), (1983, 910), (1984, 918), (1985, 923), (1986, 921), (1987, 931), (1988, 1004), (1989, 951), (1990, 1014), (1991, 964), (1992, 944), (1993, 951), (1994, 998), (1995, 958), (1996, 984), (1997, 983), (1998, 1058), (1999, 1014), (2000, 973), (2001, 975), (2002, 977), (2003, 981), (2004, 991), (2005, 990), (2006, 989), (2007, 989), (2008, 988), (2009, 988), (2010, 988)

NG_area = GRAPH(TIME)

(1980, 392832), (1981, 392832), (1982, 392832), (1983, 392832), (1984, 392832), (1985, 392832), (1986, 392832), (1987, 392832), (1988, 392832), (1989, 392832), (1990, 392832), (1991, 392832), (1992, 392832), (1993, 392832), (1994, 392832), (1995, 392832), (1996, 392832), (1997, 392832), (1998, 392832), (1999, 392832), (2000, 392832), (2001, 392832), (2002, 392832), (2003, 392832), (2004, 392832), (2005, 392832), (2006, 392832), (2007, 392832), (2008, 392832), (2009, 392832), (2010, 392832)

Groundwater subsystem

Groundwater(t) = Groundwater(t - dt) + (GWIN) * dt

INIT Groundwater = 0

INFLOWS:

GWIN = GWIN\Leaching

GWIN\Leaching = CLOUT\Leaching + GLOUT\Leaching + HMOUT\Leaching + UGOUT\Leaching + ARRAYSUM(LSOUT\Leaching[*]) + WTOUT\Leaching + GTAcc

Human Subsystem

Human(t) = Human(t - dt) + (HMIN - HMOUT) * dt

INIT Human = 0

INFLOWS:

HMIN =
ARRAYSUM(HMIN\Animal[*])+ARRAYSUM(HMIN\Fish[*])+ARRAYSUM(HMIN\
Grain[*])+HMIN\Fuel+HMIN\Goods+HMIN\Straw

OUTFLOWS:

HMOUT =
HMOUT\Burning+ARRAYSUM(HMOUT\Discharged[*])+HMOUT\Landfill+HMOU
T\Leaching+ARRAYSUM(HMOUT\Manure[*])+HMOUT\NH3+HMOUT\Residue+A
RRAYSUM(HMOUT\Treated[*])

Population(t) = Population(t - dt) + (Population_change) * dt

INIT Population = 98705

INFLOWS:

Population_change = Population*Growth_rate/1000

HMAcc = HMIN-HMOUT

HMIN\Animal[Urbanization] =
Population*Human_index[Urbanization,Meat]*Human_index[Urbanization,Population_ra
tio]/10^7

HMIN\Fish[Urbanization] =
Population*Human_index[Urbanization,Fish]*Human_index[Urbanization,Population_rat
io]/10^7

HMIN\Goods = IDOUT\Na_nonstructural + IDOUT\Na_structural +
IDOUT\Nb_nonstructural + IDOUT\Nb_structural

HMIN\Grain[Urbanization] =
Population*Human_index[Urbanization,Grain]*Human_index[Urbanization,Population_r
atio]/10^7

HMIN\Straw = ARRAYSUM(CLOUT\Straw[*])*Straw_fuel_ratio

HMOUT\Burning = Total_food[Urban]*0.1*0.1+ IDOUT\Nb_nonstructural+
IDOUT\Na_nonstructural*0.5 + HMIN\Fuel + HMIN\Straw

HMOUT\Discharged[Urbanization] = (Total_food[Urbanization]*0.9*0.91-
Population*Human_index[Urbanization,Population_ratio]*Human_index[Urbanization,N
H3]/10^7)*Human_index[Urbanization,Discharged_ratio]/100

HMOUT\Landfill = (IDOUT\Na_structural + IDOUT\Nb_structural)/2+ +
Total_food[Urban]*0.1*0.9

HMOUT\Leaching = ARRAYSUM(Total_food[*])*0.9*0.09

HMOUT\Manure[Urbanization] = (Total_food[Urbanization]*0.9*0.91-
Population*Human_index[Urbanization,Population_ratio]*Human_index[Urbanization,N
H3]/10^7)*Human_index[Urbanization,Recycled_ratio]/100

HMOUT\NH3 =
Population*(Human_index[Urban,Population_ratio]*Human_index[Urban,NH3]+Human

_index[Rural,Population_ratio]*Human_index[Rural,NH3])/10^7

HMOUT\Residue = Total_food[Rural]*0.1

HMOUT\Treated[Urbanization] = (Total_food[Urbanization]*0.9*0.91-Population*Human_index[Urbanization,Population_ratio]*Human_index[Urbanization,NH3]/10^7)*Human_index[Urbanization,Treated_ratio]/100

Total_food[Urbanization] = (HMIN\Animal[Urbanization]+HMIN\Fish[Urbanization]+HMIN\Grain[Urbanization])

Growth_rate = GRAPH(TIME)
(1980, 11.9), (1981, 14.6), (1982, 15.7), (1983, 13.3), (1984, 13.1), (1985, 14.3), (1986, 15.6), (1987, 16.6), (1988, 15.7), (1989, 15.0), (1990, 14.4), (1991, 13.0), (1992, 11.6), (1993, 11.4), (1994, 11.2), (1995, 10.6), (1996, 10.4), (1997, 10.1), (1998, 9.14), (1999, 8.18), (2000, 7.58), (2001, 6.95), (2002, 6.45), (2003, 6.01), (2004, 5.87), (2005, 5.89), (2006, 5.28), (2007, 5.17), (2008, 5.08), (2009, 4.87), (2010, 4.79)

HMIN\Fuel = GRAPH(TIME)
(1980, 0.21), (1981, 0.22), (1982, 0.23), (1983, 0.24), (1984, 0.26), (1985, 0.3), (1986, 0.31), (1987, 0.32), (1988, 0.35), (1989, 0.35), (1990, 0.36), (1991, 0.36), (1992, 0.35), (1993, 0.36), (1994, 0.35), (1995, 0.35), (1996, 0.4), (1997, 0.36), (1998, 0.32), (1999, 0.32), (2000, 0.35), (2001, 0.33), (2002, 0.38), (2003, 0.43), (2004, 0.46), (2005, 0.56), (2006, 0.61), (2007, 0.68), (2008, 0.7), (2009, 0.74), (2010, 0.75)

Human_index[Urban,Grain] = GRAPH(TIME)
(1980, 3.04), (1981, 3.10), (1982, 3.26), (1983, 3.36), (1984, 3.40), (1985, 3.38), (1986, 3.37), (1987, 3.36), (1988, 3.31), (1989, 3.27), (1990, 3.37), (1991, 3.21), (1992, 3.26), (1993, 3.44), (1994, 3.51), (1995, 3.53), (1996, 3.55), (1997, 3.60), (1998, 3.59), (1999, 3.52), (2000, 3.61), (2001, 3.58), (2002, 3.57), (2003, 3.51), (2004, 3.52), (2005, 3.55), (2006, 3.50), (2007, 3.50), (2008, 3.54), (2009, 3.56), (2010, 3.57)

Human_index[Urban,Meat] = GRAPH(TIME)
(1980, 0.4), (1981, 0.41), (1982, 0.44), (1983, 0.45), (1984, 0.49), (1985, 0.55), (1986, 0.59), (1987, 0.61), (1988, 0.67), (1989, 0.69), (1990, 0.74), (1991, 0.81), (1992, 0.88), (1993, 0.97), (1994, 1.09), (1995, 1.18), (1996, 1.21), (1997, 1.31), (1998, 1.39), (1999, 1.45), (2000, 1.48), (2001, 1.48), (2002, 1.52), (2003, 1.58), (2004, 1.62), (2005, 1.68), (2006, 1.71), (2007, 1.71), (2008, 1.80), (2009, 1.85), (2010, 1.87)

Human_index[Urban,Fish] = GRAPH(TIME)
(1980, 0.09), (1981, 0.09), (1982, 0.1), (1983, 0.1), (1984, 0.1), (1985, 0.12), (1986, 0.14), (1987, 0.16), (1988, 0.16), (1989, 0.17), (1990, 0.18), (1991, 0.19), (1992, 0.2), (1993, 0.23), (1994, 0.27), (1995, 0.31), (1996, 0.34), (1997, 0.34), (1998, 0.35), (1999, 0.35), (2000, 0.36), (2001, 0.36), (2002, 0.37), (2003, 0.39), (2004, 0.4), (2005, 0.41), (2006, 0.42), (2007, 0.45), (2008, 0.47), (2009, 0.47), (2010, 0.48)

Human_index[Urban,Treated_ratio] = GRAPH(TIME)
(1980, 4.98), (1981, 5.69), (1982, 5.95), (1983, 6.45), (1984, 8.99), (1985, 9.21), (1986, 10.2), (1987, 10.4), (1988, 11.0), (1989, 12.2), (1990, 13.1), (1991, 14.9), (1992, 17.1), (1993, 17.3), (1994, 19.7), (1995, 20.0), (1996, 23.6), (1997, 25.8), (1998, 29.6), (1999, 31.9), (2000, 34.3),

(2001, 36.4), (2002, 40.0), (2003, 42.4), (2004, 45.7), (2005, 52.0), (2006, 57.9), (2007, 62.0), (2008, 66.0), (2009, 73.0), (2010, 75.0)

Human_index[Urban,Recycled_ratio] = GRAPH(TIME)

(1980, 90.0), (1981, 88.3), (1982, 87.1), (1983, 85.6), (1984, 82.1), (1985, 80.9), (1986, 79.0), (1987, 77.7), (1988, 76.1), (1989, 74.0), (1990, 72.1), (1991, 69.4), (1992, 66.2), (1993, 65.0), (1994, 61.6), (1995, 60.3), (1996, 55.7), (1997, 52.5), (1998, 47.8), (1999, 44.5), (2000, 41.2), (2001, 38.0), (2002, 33.5), (2003, 30.1), (2004, 25.9), (2005, 20.3), (2006, 15.0), (2007, 12.0), (2008, 10.0), (2009, 8.00), (2010, 5.00)

Human_index[Urban,Discharged_ratio] = GRAPH(TIME)

(1980, 5.02), (1981, 6.00), (1982, 6.98), (1983, 7.95), (1984, 8.93), (1985, 9.91), (1986, 10.9), (1987, 11.9), (1988, 12.8), (1989, 13.8), (1990, 14.8), (1991, 15.8), (1992, 16.8), (1993, 17.7), (1994, 18.7), (1995, 19.7), (1996, 20.7), (1997, 21.6), (1998, 22.6), (1999, 23.6), (2000, 24.6), (2001, 25.6), (2002, 26.5), (2003, 27.5), (2004, 28.5), (2005, 27.7), (2006, 27.1), (2007, 26.0), (2008, 24.0), (2009, 19.0), (2010, 20.0)

Human_index[Urban,Population_ratio] = GRAPH(TIME)

(1980, 19.4), (1981, 20.2), (1982, 21.1), (1983, 21.6), (1984, 23.0), (1985, 23.7), (1986, 24.5), (1987, 25.3), (1988, 25.8), (1989, 26.2), (1990, 26.4), (1991, 26.9), (1992, 27.5), (1993, 28.0), (1994, 28.5), (1995, 29.0), (1996, 30.5), (1997, 31.9), (1998, 33.4), (1999, 34.8), (2000, 36.2), (2001, 37.7), (2002, 39.1), (2003, 40.5), (2004, 41.8), (2005, 43.0), (2006, 43.9), (2007, 44.9), (2008, 45.7), (2009, 48.3), (2010, 50.0)

Human_index[Urban,NH3] = GRAPH(TIME)

(1980, 0.25), (1981, 0.25), (1982, 0.25), (1983, 0.25), (1984, 0.25), (1985, 0.25), (1986, 0.25), (1987, 0.25), (1988, 0.25), (1989, 0.25), (1990, 0.25), (1991, 0.25), (1992, 0.25), (1993, 0.25), (1994, 0.25), (1995, 0.25), (1996, 0.25), (1997, 0.25), (1998, 0.25), (1999, 0.25), (2000, 0.25), (2001, 0.25), (2002, 0.25), (2003, 0.25), (2004, 0.25), (2005, 0.25), (2006, 0.25), (2007, 0.25), (2008, 0.25), (2009, 0.25), (2010, 0.25)

Human_index[Rural,Grain] = GRAPH(TIME)

(1980, 2.64), (1981, 2.70), (1982, 2.84), (1983, 2.92), (1984, 2.95), (1985, 2.94), (1986, 2.93), (1987, 2.92), (1988, 2.88), (1989, 2.84), (1990, 2.93), (1991, 2.79), (1992, 2.83), (1993, 2.99), (1994, 3.05), (1995, 3.07), (1996, 3.08), (1997, 3.13), (1998, 3.12), (1999, 3.06), (2000, 3.14), (2001, 3.11), (2002, 3.10), (2003, 3.05), (2004, 3.06), (2005, 3.08), (2006, 3.04), (2007, 3.05), (2008, 3.08), (2009, 3.09), (2010, 3.11)

Human_index[Rural,Meat] = GRAPH(TIME)

(1980, 0.35), (1981, 0.36), (1982, 0.38), (1983, 0.39), (1984, 0.43), (1985, 0.48), (1986, 0.51), (1987, 0.53), (1988, 0.58), (1989, 0.6), (1990, 0.64), (1991, 0.7), (1992, 0.77), (1993, 0.85), (1994, 0.95), (1995, 1.03), (1996, 1.06), (1997, 1.14), (1998, 1.21), (1999, 1.26), (2000, 1.29), (2001, 1.29), (2002, 1.32), (2003, 1.37), (2004, 1.41), (2005, 1.46), (2006, 1.49), (2007, 1.49), (2008, 1.57), (2009, 1.61), (2010, 1.63)

Human_index[Rural,Fish] = GRAPH(TIME)

(1980, 0.08), (1981, 0.08), (1982, 0.08), (1983, 0.08), (1984, 0.09), (1985, 0.1), (1986, 0.12), (1987, 0.14), (1988, 0.14), (1989, 0.15), (1990, 0.16), (1991, 0.16), (1992, 0.17), (1993, 0.2), (1994, 0.24), (1995, 0.27), (1996, 0.3), (1997, 0.3), (1998, 0.31), (1999, 0.31), (2000, 0.32), (2001, 0.32), (2002,

0.33), (2003, 0.34), (2004, 0.35), (2005, 0.36), (2006, 0.37), (2007, 0.39), (2008, 0.41), (2009, 0.41), (2010, 0.42)

Human_index[Rural,Treated_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.3), (1988, 0.6), (1989, 0.9), (1990, 1.20), (1991, 1.50), (1992, 1.80), (1993, 2.10), (1994, 2.40), (1995, 2.70), (1996, 3.00), (1997, 3.30), (1998, 3.60), (1999, 3.90), (2000, 4.20), (2001, 4.50), (2002, 4.80), (2003, 5.10), (2004, 5.40), (2005, 5.70), (2006, 6.00), (2007, 6.30), (2008, 6.60), (2009, 6.90), (2010, 7.20)

Human_index[Rural,Recycled_ratio] = GRAPH(TIME)

(1980, 95.0), (1981, 94.9), (1982, 94.8), (1983, 94.7), (1984, 94.6), (1985, 94.5), (1986, 94.3), (1987, 94.2), (1988, 94.1), (1989, 94.0), (1990, 93.9), (1991, 93.8), (1992, 93.7), (1993, 93.7), (1994, 91.3), (1995, 89.0), (1996, 86.6), (1997, 84.2), (1998, 81.8), (1999, 79.5), (2000, 77.1), (2001, 74.7), (2002, 72.4), (2003, 70.0), (2004, 67.6), (2005, 65.3), (2006, 62.9), (2007, 60.5), (2008, 58.1), (2009, 55.8), (2010, 53.4)

Human_index[Rural,Discharged_ratio] = GRAPH(TIME)

(1980, 5.00), (1981, 5.11), (1982, 5.22), (1983, 5.33), (1984, 5.43), (1985, 5.54), (1986, 5.65), (1987, 5.46), (1988, 5.27), (1989, 5.08), (1990, 4.88), (1991, 4.69), (1992, 4.50), (1993, 4.20), (1994, 6.27), (1995, 8.34), (1996, 10.4), (1997, 12.5), (1998, 14.6), (1999, 16.6), (2000, 18.7), (2001, 20.8), (2002, 22.8), (2003, 24.9), (2004, 27.0), (2005, 29.0), (2006, 31.1), (2007, 33.2), (2008, 35.3), (2009, 37.3), (2010, 39.4)

Human_index[Rural,Population_ratio] = GRAPH(TIME)

(1980, 80.6), (1981, 79.8), (1982, 78.9), (1983, 78.4), (1984, 77.0), (1985, 76.3), (1986, 75.5), (1987, 74.7), (1988, 74.2), (1989, 73.8), (1990, 73.6), (1991, 73.1), (1992, 72.5), (1993, 72.0), (1994, 71.5), (1995, 71.0), (1996, 69.5), (1997, 68.1), (1998, 66.7), (1999, 65.2), (2000, 63.8), (2001, 62.3), (2002, 60.9), (2003, 59.5), (2004, 58.2), (2005, 57.0), (2006, 56.1), (2007, 55.1), (2008, 54.3), (2009, 51.7), (2010, 50.0)

Human_index[Rural,NH3] = GRAPH(TIME)

(1980, 0.5), (1981, 0.5), (1982, 0.5), (1983, 0.5), (1984, 0.5), (1985, 0.5), (1986, 0.5), (1987, 0.5), (1988, 0.5), (1989, 0.5), (1990, 0.5), (1991, 0.5), (1992, 0.5), (1993, 0.5), (1994, 0.5), (1995, 0.5), (1996, 0.5), (1997, 0.5), (1998, 0.5), (1999, 0.5), (2000, 0.5), (2001, 0.5), (2002, 0.5), (2003, 0.5), (2004, 0.5), (2005, 0.5), (2006, 0.5), (2007, 0.5), (2008, 0.5), (2009, 0.5), (2010, 0.5)

Straw_fuel_ratio = GRAPH(TIME)

(1980, 0.56), (1981, 0.54), (1982, 0.52), (1983, 0.51), (1984, 0.48), (1985, 0.47), (1986, 0.46), (1987, 0.44), (1988, 0.42), (1989, 0.41), (1990, 0.39), (1991, 0.38), (1992, 0.36), (1993, 0.35), (1994, 0.33), (1995, 0.32), (1996, 0.33), (1997, 0.34), (1998, 0.35), (1999, 0.36), (2000, 0.31), (2001, 0.33), (2002, 0.32), (2003, 0.33), (2004, 0.31), (2005, 0.3), (2006, 0.29), (2007, 0.29), (2008, 0.28), (2009, 0.27), (2010, 0.26)

Industry subsystem

Industry(t) = Industry(t - dt) + (IDIN - IDOUT) * dt

INIT Industry = 0

INFLOWS:

IDIN = IDIN\Straw+IDIN\Fuel+IDIN\HBNF+IDIN\LS_material+IDIN\CL_material+IDIN\Wood

OUTFLOWS:

IDOUT = IDOUT\Fertilizer+IDOUT\N2O+IDOUT\Na_nonstructural+IDOUT\Na_structural+IDOUT\Nb_nonstructural+IDOUT\Nb_structural+IDOUT\NOx+IDOUT\Wastewater

IDIN\CL_material = (CLOUT\Crop[cotton]+CLOUT\Crop[hemp]+CLOUT\Crop[tobacco])/10^4

IDIN\HBNF = IDOUT\Fertilizer + IDOUT\Na_nonstructural + IDOUT\Na_structural + IDOUT\Wastewater + IDOUT\N2O

IDIN\LS_material = ARRAYSUM(LSOUT\Material[*]) + ARRAYSUM(GLOUT\Material[*])

IDIN\Straw = ARRAYSUM(CLOUT\Straw[*])*Straw_ID_ratio

IDIN\Wood = FROUT\Wood

IDOUT\Fertilizer = AQIN\Fertilizer + CLIN\Fertilizer + GLIN\Fertilizer + LSIN\fertilizer + UGIN\Fertilizer

IDOUT\Nb_nonstructural = CLOUT\Crop[tobacco]

IDOUT\Nb_structural = CLOUT\Crop[cotton]+ CLOUT\Crop[hemp] + IDIN\LS_material + IDIN\Straw/2 + IDIN\Wood

IDOUT\NOx = IDIN\Fuel

IDIN\Fuel = GRAPH(TIME)

(1980, 1.09), (1981, 1.06), (1982, 1.11), (1983, 1.18), (1984, 1.28), (1985, 1.37), (1986, 1.45), (1987, 1.57), (1988, 1.68), (1989, 1.77), (1990, 1.80), (1991, 1.91), (1992, 2.03), (1993, 2.16), (1994, 2.32), (1995, 2.40), (1996, 2.50), (1997, 2.51), (1998, 2.55), (1999, 2.65), (2000, 2.69), (2001, 2.77), (2002, 2.91), (2003, 3.42), (2004, 3.99), (2005, 4.40), (2006, 4.83), (2007, 5.22), (2008, 5.39), (2009, 5.64), (2010, 5.90)

IDOUT\N2O = GRAPH(TIME)

(1980, 0.03), (1981, 0.02), (1982, 0.02), (1983, 0.02), (1984, 0.02), (1985, 0.02), (1986, 0.02), (1987, 0.02), (1988, 0.02), (1989, 0.02), (1990, 0.02), (1991, 0.02), (1992, 0.02), (1993, 0.02), (1994, 0.01), (1995, 0.02), (1996, 0.01), (1997, 0.01), (1998, 0.01), (1999, 0.01), (2000, 0.01), (2001, 0.01), (2002, 0.01), (2003, 0.01), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

IDOUT\Na_nonstructural = GRAPH(TIME)

(1980, 0.15), (1981, 0.17), (1982, 0.2), (1983, 0.22), (1984, 0.25), (1985, 0.27), (1986, 0.3), (1987, 0.32), (1988, 0.34), (1989, 0.36), (1990, 0.43), (1991, 0.52), (1992, 0.61), (1993, 0.58), (1994, 0.63), (1995, 0.63), (1996, 0.7), (1997, 0.73), (1998, 0.76), (1999, 0.77), (2000, 0.77), (2001, 0.9), (2002, 0.95), (2003, 0.94), (2004, 0.98), (2005, 0.98), (2006, 1.05), (2007, 1.13), (2008, 1.10), (2009, 1.19), (2010, 1.37)

IDOUT\Na_structural = GRAPH(TIME)

(1980, 0.11), (1981, 0.12), (1982, 0.14), (1983, 0.15), (1984, 0.17), (1985, 0.18), (1986, 0.19), (1987, 0.2), (1988, 0.21), (1989, 0.22), (1990, 0.24), (1991, 0.27), (1992, 0.31), (1993, 0.32), (1994,

0.36), (1995, 0.49), (1996, 0.5), (1997, 0.57), (1998, 0.6), (1999, 0.66), (2000, 0.75), (2001, 0.84), (2002, 0.97), (2003, 1.15), (2004, 1.58), (2005, 1.69), (2006, 2.15), (2007, 2.52), (2008, 2.58), (2009, 3.00), (2010, 3.65)

IDOUT\Wastewater = GRAPH(TIME)

(1980,), (1981,), (1982,), (1983,), (1984,), (1985,), (1986,), (1987,), (1988,), (1989,), (1990,), (1991,), (1992,), (1993,), (1994,), (1995,), (1996,), (1997,), (1998, 0.4), (1999,), (2000,), (2001,), (2002, 0.41), (2003, 0.4), (2004, 0.37), (2005, 0.38), (2006, 0.39), (2007, 0.37), (2008, 0.35), (2009, 0.3), (2010, 0.28)

Straw_ID_ratio = GRAPH(TIME)

(1980, 0.01), (1981, 0.01), (1982, 0.01), (1983, 0.01), (1984, 0.01), (1985, 0.01), (1986, 0.01), (1987, 0.01), (1988, 0.02), (1989, 0.02), (1990, 0.02), (1991, 0.02), (1992, 0.02), (1993, 0.02), (1994, 0.02), (1995, 0.02), (1996, 0.03), (1997, 0.03), (1998, 0.03), (1999, 0.03), (2000, 0.04), (2001, 0.04), (2002, 0.04), (2003, 0.05), (2004, 0.04), (2005, 0.05), (2006, 0.05), (2007, 0.06), (2008, 0.06), (2009, 0.06), (2010, 0.06)

Livestock subsystem

Livestock(t) = Livestock(t - dt) + (LSIN - LSOUT) * dt

INIT Livestock = 0

INFLOWS:

LSIN =

LSIN\fertilizer+LSIN\Fish+LSIN\food_res+LSIN\grain+LSIN\import+LSIN\Straw

OUTFLOWS:

LSOUT =

ARRAYSUM(LSOUT\Cropland[*])+ARRAYSUM(LSOUT\Leaching[*])+ARRAYSUM(LSOUT\Material[*])+ARRAYSUM(LSOUT\Meat[*])+ARRAYSUM(LSOUT\NH3[*])+ARRAYSUM(LSOUT\Runoff[*])

LSIN\fertilizer = LSIN\Straw*1.5

LSIN\Fish = ARRAYSUM(AQOUT\Fish[*]) - ARRAYSUM(HMIN\Fish[*])

LSIN\food_res = HMOUT\Residue

LSIN\grain = ARRAYSUM(CLOUT\Crop[*]) - ARRAYSUM(HMIN\Grain[*]) - AQIN\Grain

LSIN\import = LSOUT - LSIN\Fish - LSIN\food_res - LSIN\grain - LSIN\Straw- LSIN\fertilizer

LSIN\Straw = arraysum(CLOUT\Straw[*])*Straw_feed_ratio

LSOUT\Cropland[Animal] =

Livestock_index[Animal,Livestock_numbers]*Livestock_index[Animal,Livestock_excretion]*(1-Livestock_index[Animal,Livestock_grassland_ratio])/10^6-LSOUT\NH3[Animal]-LSOUT\Runoff[Animal]-LSOUT\Leaching[Animal]

LSOUT\Leaching[Animal] =

Livestock_index[Animal,Livestock_numbers]*(Livestock_index[Animal,Livestock_excretion]-Livestock_index[Animal,Livestock_total_NH3])*0.05*(1-Livestock_index[Animal,Livestock_grassland_ratio])/10^6

LSOUT\Material[Animal] =
Livestock_index[Animal,Livestock_material_production]*Livestock_index[Animal,Livestock_material_N_concen]*(1-Livestock_index[Animal,Livestock_grassland_ratio])/10^8
LSOUT\Meat[Animal] =
Livestock_index[Animal,Livestock_production]*Livestock_index[Animal,Livestock_N_concen]*(1-Livestock_index[Animal,Livestock_grassland_ratio])/10^8
LSOUT\NH3[Animal] =
Livestock_index[Animal,Livestock_numbers]*Livestock_index[Animal,Livestock_total_NH3]*(1-Livestock_index[Animal,Livestock_grassland_ratio])/10^6*0.72
LSOUT\Runoff[Animal] =
Livestock_index[Animal,Livestock_numbers]*(Livestock_index[Animal,Livestock_excretion]-Livestock_index[Animal,Livestock_total_NH3])*0.35*(1-
Livestock_index[Animal,Livestock_grassland_ratio])/10^6
Livestock_index[Chicken,Livestock_production] = GRAPH(TIME)
(1980, 959010), (1981, 986340), (1982, 1e+006), (1983, 1.1e+006), (1984, 1.1e+006), (1985, 1.2e+006), (1986, 1.3e+006), (1987, 1.6e+006), (1988, 2e+006), (1989, 2e+006), (1990, 2.2e+006), (1991, 2.7e+006), (1992, 3.1e+006), (1993, 4.1e+006), (1994, 4.7e+006), (1995, 5.6e+006), (1996, 5.6e+006), (1997, 6.6e+006), (1998, 7.3e+006), (1999, 7.5e+006), (2000, 8.4e+006), (2001, 8.2e+006), (2002, 8.6e+006), (2003, 8.8e+006), (2004, 8.9e+006), (2005, 9.4e+006), (2006, 9.6e+006), (2007, 1e+007), (2008, 1.1e+007), (2009, 1.1e+007), (2010, 1.2e+007)
Livestock_index[Chicken,Livestock_excretion] = GRAPH(TIME)
(1980, 0.46), (1981, 0.46), (1982, 0.46), (1983, 0.46), (1984, 0.46), (1985, 0.46), (1986, 0.46), (1987, 0.46), (1988, 0.46), (1989, 0.46), (1990, 0.46), (1991, 0.46), (1992, 0.46), (1993, 0.46), (1994, 0.46), (1995, 0.46), (1996, 0.46), (1997, 0.46), (1998, 0.46), (1999, 0.46), (2000, 0.46), (2001, 0.46), (2002, 0.46), (2003, 0.46), (2004, 0.46), (2005, 0.46), (2006, 0.46), (2007, 0.46), (2008, 0.46), (2009, 0.46), (2010, 0.46)
Livestock_index[Chicken,Livestock_total_NH3] = GRAPH(TIME)
(1980, 0.23), (1981, 0.23), (1982, 0.23), (1983, 0.23), (1984, 0.23), (1985, 0.23), (1986, 0.23), (1987, 0.23), (1988, 0.23), (1989, 0.23), (1990, 0.23), (1991, 0.23), (1992, 0.23), (1993, 0.23), (1994, 0.23), (1995, 0.23), (1996, 0.23), (1997, 0.23), (1998, 0.23), (1999, 0.23), (2000, 0.23), (2001, 0.23), (2002, 0.23), (2003, 0.23), (2004, 0.23), (2005, 0.23), (2006, 0.23), (2007, 0.23), (2008, 0.23), (2009, 0.23), (2010, 0.23)
Livestock_index[Chicken,Livestock_storaged_NH3] = GRAPH(TIME)
(1980, 0.13), (1981, 0.13), (1982, 0.13), (1983, 0.13), (1984, 0.13), (1985, 0.13), (1986, 0.13), (1987, 0.13), (1988, 0.13), (1989, 0.13), (1990, 0.13), (1991, 0.13), (1992, 0.13), (1993, 0.13), (1994, 0.13), (1995, 0.13), (1996, 0.13), (1997, 0.13), (1998, 0.13), (1999, 0.13), (2000, 0.13), (2001, 0.13), (2002, 0.13), (2003, 0.13), (2004, 0.13), (2005, 0.13), (2006, 0.13), (2007, 0.13), (2008, 0.13), (2009, 0.13), (2010, 0.13)
Livestock_index[Chicken,Livestock_manure_NH3] = GRAPH(TIME)
(1980, 0.09), (1981, 0.09), (1982, 0.09), (1983, 0.09), (1984, 0.09), (1985, 0.09), (1986, 0.09), (1987, 0.09), (1988, 0.09), (1989, 0.09), (1990, 0.09), (1991, 0.09), (1992, 0.09), (1993, 0.09),

(1994, 0.09), (1995, 0.09), (1996, 0.09), (1997, 0.09), (1998, 0.09), (1999, 0.09), (2000, 0.09), (2001, 0.09), (2002, 0.09), (2003, 0.09), (2004, 0.09), (2005, 0.09), (2006, 0.09), (2007, 0.09), (2008, 0.09), (2009, 0.09), (2010, 0.09)

Livestock_index[Chicken,Livestock_material_production] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Chicken,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Chicken,Livestock_N_concen] = GRAPH(TIME)

(1980, 3.09), (1981, 3.09), (1982, 3.09), (1983, 3.09), (1984, 3.09), (1985, 3.09), (1986, 3.09), (1987, 3.09), (1988, 3.09), (1989, 3.09), (1990, 3.09), (1991, 3.09), (1992, 3.09), (1993, 3.09), (1994, 3.09), (1995, 3.09), (1996, 3.09), (1997, 3.09), (1998, 3.09), (1999, 3.09), (2000, 3.09), (2001, 3.09), (2002, 3.09), (2003, 3.09), (2004, 3.09), (2005, 3.09), (2006, 3.09), (2007, 3.09), (2008, 3.09), (2009, 3.09), (2010, 3.09)

Livestock_index[Chicken,Livestock_numbers] = GRAPH(TIME)

(1980, 940000), (1981, 965000), (1982, 1e+006), (1983, 1e+006), (1984, 1.1e+006), (1985, 1.1e+006), (1986, 1.3e+006), (1987, 1.4e+006), (1988, 1.7e+006), (1989, 1.7e+006), (1990, 1.8e+006), (1991, 2.1e+006), (1992, 2.4e+006), (1993, 3.1e+006), (1994, 3.4e+006), (1995, 4.1e+006), (1996, 4.2e+006), (1997, 5.1e+006), (1998, 5.4e+006), (1999, 5.8e+006), (2000, 6.2e+006), (2001, 6e+006), (2002, 6.2e+006), (2003, 6.5e+006), (2004, 6.5e+006), (2005, 6.9e+006), (2006, 6.8e+006), (2007, 7.3e+006), (2008, 7.8e+006), (2009, 8.1e+006), (2010, 8.4e+006)

Livestock_index[Chicken,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Duck,Livestock_production] = GRAPH(TIME)

(1980, 240000), (1981, 240000), (1982, 245000), (1983, 250000), (1984, 257500), (1985, 270000), (1986, 338713), (1987, 386931), (1988, 436090), (1989, 454133), (1990, 510668), (1991, 585941), (1992, 708871), (1993, 892320), (1994, 1e+006), (1995, 1.2e+006), (1996, 1.2e+006), (1997, 1.4e+006), (1998, 1.5e+006), (1999, 1.8e+006), (2000, 1.8e+006), (2001, 1.9e+006), (2002, 1.8e+006), (2003, 1.9e+006), (2004, 1.9e+006), (2005, 2.1e+006), (2006, 2.1e+006), (2007, 2.2e+006), (2008, 2.4e+006), (2009, 2.5e+006), (2010, 2.7e+006)

Livestock_index[Duck,Livestock_excretion] = GRAPH(TIME)
(1980, 0.47), (1981, 0.47), (1982, 0.47), (1983, 0.47), (1984, 0.47), (1985, 0.47), (1986, 0.47),
(1987, 0.47), (1988, 0.47), (1989, 0.47), (1990, 0.47), (1991, 0.47), (1992, 0.47), (1993, 0.47),
(1994, 0.47), (1995, 0.47), (1996, 0.47), (1997, 0.47), (1998, 0.47), (1999, 0.47), (2000, 0.47),
(2001, 0.47), (2002, 0.47), (2003, 0.47), (2004, 0.47), (2005, 0.47), (2006, 0.47), (2007, 0.47),
(2008, 0.47), (2009, 0.47), (2010, 0.47)
Livestock_index[Duck,Livestock_total_NH3] = GRAPH(TIME)
(1980, 0.25), (1981, 0.25), (1982, 0.25), (1983, 0.25), (1984, 0.25), (1985, 0.25), (1986, 0.25),
(1987, 0.25), (1988, 0.25), (1989, 0.25), (1990, 0.25), (1991, 0.25), (1992, 0.25), (1993, 0.25),
(1994, 0.25), (1995, 0.25), (1996, 0.25), (1997, 0.25), (1998, 0.25), (1999, 0.25), (2000, 0.25),
(2001, 0.25), (2002, 0.25), (2003, 0.25), (2004, 0.25), (2005, 0.25), (2006, 0.25), (2007, 0.25),
(2008, 0.25), (2009, 0.25), (2010, 0.25)
Livestock_index[Duck,Livestock_storaged_NH3] = GRAPH(TIME)
(1980, 0.16), (1981, 0.16), (1982, 0.16), (1983, 0.16), (1984, 0.16), (1985, 0.16), (1986, 0.16),
(1987, 0.16), (1988, 0.16), (1989, 0.16), (1990, 0.16), (1991, 0.16), (1992, 0.16), (1993, 0.16),
(1994, 0.16), (1995, 0.16), (1996, 0.16), (1997, 0.16), (1998, 0.16), (1999, 0.16), (2000, 0.16),
(2001, 0.16), (2002, 0.16), (2003, 0.16), (2004, 0.16), (2005, 0.16), (2006, 0.16), (2007, 0.16),
(2008, 0.16), (2009, 0.16), (2010, 0.16)
Livestock_index[Duck,Livestock_manure_NH3] = GRAPH(TIME)
(1980, 0.08), (1981, 0.08), (1982, 0.08), (1983, 0.08), (1984, 0.08), (1985, 0.08), (1986, 0.08),
(1987, 0.08), (1988, 0.08), (1989, 0.08), (1990, 0.08), (1991, 0.08), (1992, 0.08), (1993, 0.08),
(1994, 0.08), (1995, 0.08), (1996, 0.08), (1997, 0.08), (1998, 0.08), (1999, 0.08), (2000, 0.08),
(2001, 0.08), (2002, 0.08), (2003, 0.08), (2004, 0.08), (2005, 0.08), (2006, 0.08), (2007, 0.08),
(2008, 0.08), (2009, 0.08), (2010, 0.08)
Livestock_index[Duck,Livestock_material_production] = GRAPH(TIME)
(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00),
(1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00),
(1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00),
(2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00),
(2008, 0.00), (2009, 0.00), (2010, 0.00)
Livestock_index[Duck,Livestock_material_N_concen] = GRAPH(TIME)
(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00),
(1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00),
(1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00),
(2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00),
(2008, 0.00), (2009, 0.00), (2010, 0.00)
Livestock_index[Duck,Livestock_N_concen] = GRAPH(TIME)
(1980, 2.48), (1981, 2.48), (1982, 2.48), (1983, 2.48), (1984, 2.48), (1985, 2.48), (1986, 2.48),
(1987, 2.48), (1988, 2.48), (1989, 2.48), (1990, 2.48), (1991, 2.48), (1992, 2.48), (1993, 2.48),
(1994, 2.48), (1995, 2.48), (1996, 2.48), (1997, 2.48), (1998, 2.48), (1999, 2.48), (2000, 2.48),
(2001, 2.48), (2002, 2.48), (2003, 2.48), (2004, 2.48), (2005, 2.48), (2006, 2.48), (2007, 2.48),
(2008, 2.48), (2009, 2.48), (2010, 2.48)

Livestock_index[Duck,Livestock_numbers] = GRAPH(TIME)
(1980, 192000), (1981, 192000), (1982, 196000), (1983, 200000), (1984, 206000), (1985, 216000), (1986, 254000), (1987, 292000), (1988, 330000), (1989, 343000), (1990, 387000), (1991, 482000), (1992, 540000), (1993, 685000), (1994, 769000), (1995, 925000), (1996, 957000), (1997, 1.1e+006), (1998, 1.2e+006), (1999, 1.5e+006), (2000, 1.4e+006), (2001, 1.4e+006), (2002, 1.4e+006), (2003, 1.5e+006), (2004, 1.5e+006), (2005, 1.6e+006), (2006, 1.6e+006), (2007, 1.7e+006), (2008, 1.9e+006), (2009, 1.9e+006), (2010, 2e+006)
Livestock_index[Duck,Livestock_grassland_ratio] = GRAPH(TIME)
(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)
Livestock_index[Geese,Livestock_production] = GRAPH(TIME)
(1980, 175500), (1981, 182000), (1982, 188500), (1983, 195000), (1984, 198500), (1985, 202002), (1986, 247185), (1987, 284256), (1988, 389336), (1989, 405988), (1990, 462685), (1991, 627922), (1992, 730476), (1993, 854627), (1994, 928496), (1995, 1.3e+006), (1996, 1.3e+006), (1997, 1.5e+006), (1998, 1.6e+006), (1999, 1.7e+006), (2000, 1.7e+006), (2001, 1.7e+006), (2002, 1.7e+006), (2003, 1.7e+006), (2004, 1.8e+006), (2005, 1.9e+006), (2006, 1.9e+006), (2007, 2.1e+006), (2008, 2.2e+006), (2009, 2.3e+006), (2010, 2.4e+006)
Livestock_index[Geese,Livestock_excretion] = GRAPH(TIME)
(1980, 0.47), (1981, 0.47), (1982, 0.47), (1983, 0.47), (1984, 0.47), (1985, 0.47), (1986, 0.47), (1987, 0.47), (1988, 0.47), (1989, 0.47), (1990, 0.47), (1991, 0.47), (1992, 0.47), (1993, 0.47), (1994, 0.47), (1995, 0.47), (1996, 0.47), (1997, 0.47), (1998, 0.47), (1999, 0.47), (2000, 0.47), (2001, 0.47), (2002, 0.47), (2003, 0.47), (2004, 0.47), (2005, 0.47), (2006, 0.47), (2007, 0.47), (2008, 0.47), (2009, 0.47), (2010, 0.47)
Livestock_index[Geese,Livestock_total_NH3] = GRAPH(TIME)
(1980, 0.25), (1981, 0.25), (1982, 0.25), (1983, 0.25), (1984, 0.25), (1985, 0.25), (1986, 0.25), (1987, 0.25), (1988, 0.25), (1989, 0.25), (1990, 0.25), (1991, 0.25), (1992, 0.25), (1993, 0.25), (1994, 0.25), (1995, 0.25), (1996, 0.25), (1997, 0.25), (1998, 0.25), (1999, 0.25), (2000, 0.25), (2001, 0.25), (2002, 0.25), (2003, 0.25), (2004, 0.25), (2005, 0.25), (2006, 0.25), (2007, 0.25), (2008, 0.25), (2009, 0.25), (2010, 0.25)
Livestock_index[Geese,Livestock_storaged_NH3] = GRAPH(TIME)
(1980, 0.16), (1981, 0.16), (1982, 0.16), (1983, 0.16), (1984, 0.16), (1985, 0.16), (1986, 0.16), (1987, 0.16), (1988, 0.16), (1989, 0.16), (1990, 0.16), (1991, 0.16), (1992, 0.16), (1993, 0.16), (1994, 0.16), (1995, 0.16), (1996, 0.16), (1997, 0.16), (1998, 0.16), (1999, 0.16), (2000, 0.16), (2001, 0.16), (2002, 0.16), (2003, 0.16), (2004, 0.16), (2005, 0.16), (2006, 0.16), (2007, 0.16), (2008, 0.16), (2009, 0.16), (2010, 0.16)
Livestock_index[Geese,Livestock_manure_NH3] = GRAPH(TIME)
(1980, 0.08), (1981, 0.08), (1982, 0.08), (1983, 0.08), (1984, 0.08), (1985, 0.08), (1986, 0.08), (1987, 0.08), (1988, 0.08), (1989, 0.08), (1990, 0.08), (1991, 0.08), (1992, 0.08), (1993, 0.08), (1994, 0.08), (1995, 0.08), (1996, 0.08), (1997, 0.08), (1998, 0.08), (1999, 0.08), (2000, 0.08),

(2001, 0.08), (2002, 0.08), (2003, 0.08), (2004, 0.08), (2005, 0.08), (2006, 0.08), (2007, 0.08), (2008, 0.08), (2009, 0.08), (2010, 0.08)

Livestock_index[Geese,Livestock_material_production] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Geese,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Geese,Livestock_N_concen] = GRAPH(TIME)

(1980, 2.86), (1981, 2.86), (1982, 2.86), (1983, 2.86), (1984, 2.86), (1985, 2.86), (1986, 2.86), (1987, 2.86), (1988, 2.86), (1989, 2.86), (1990, 2.86), (1991, 2.86), (1992, 2.86), (1993, 2.86), (1994, 2.86), (1995, 2.86), (1996, 2.86), (1997, 2.86), (1998, 2.86), (1999, 2.86), (2000, 2.86), (2001, 2.86), (2002, 2.86), (2003, 2.86), (2004, 2.86), (2005, 2.86), (2006, 2.86), (2007, 2.86), (2008, 2.86), (2009, 2.86), (2010, 2.86)

Livestock_index[Geese,Livestock_numbers] = GRAPH(TIME)

(1980, 54000), (1981, 56000), (1982, 58000), (1983, 60000), (1984, 61000), (1985, 62000), (1986, 71000), (1987, 83000), (1988, 115000), (1989, 121000), (1990, 138000), (1991, 177000), (1992, 180000), (1993, 206000), (1994, 225000), (1995, 325000), (1996, 334500), (1997, 371000), (1998, 408000), (1999, 422650), (2000, 431000), (2001, 432000), (2002, 420000), (2003, 435000), (2004, 443000), (2005, 478000), (2006, 479000), (2007, 530000), (2008, 554000), (2009, 580000), (2010, 603000)

Livestock_index[Geese,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Rabbit,Livestock_production] = GRAPH(TIME)

(1980, 60000), (1981, 55500), (1982, 55500), (1983, 57000), (1984, 60000), (1985, 55999), (1986, 74000), (1987, 101003), (1988, 114998), (1989, 103002), (1990, 96000), (1991, 108000), (1992, 185004), (1993, 194997), (1994, 229007), (1995, 268009), (1996, 305998), (1997, 281000), (1998, 308000), (1999, 310001), (2000, 370007), (2001, 406011), (2002, 423014), (2003, 438003), (2004, 467000), (2005, 510618), (2006, 544802), (2007, 602012), (2008, 586984), (2009, 662985), (2010, 669015)

Livestock_index[Rabbit,Livestock_excretion] = GRAPH(TIME)

(1980, 0.45), (1981, 0.45), (1982, 0.45), (1983, 0.45), (1984, 0.45), (1985, 0.45), (1986, 0.45),

(1987, 0.45), (1988, 0.45), (1989, 0.45), (1990, 0.45), (1991, 0.45), (1992, 0.45), (1993, 0.45), (1994, 0.45), (1995, 0.45), (1996, 0.45), (1997, 0.45), (1998, 0.45), (1999, 0.45), (2000, 0.45), (2001, 0.45), (2002, 0.45), (2003, 0.45), (2004, 0.45), (2005, 0.45), (2006, 0.45), (2007, 0.45), (2008, 0.45), (2009, 0.45), (2010, 0.45)

Livestock_index[Rabbit,Livestock_total_NH3] = GRAPH(TIME)

(1980, 0.2), (1981, 0.2), (1982, 0.2), (1983, 0.2), (1984, 0.2), (1985, 0.2), (1986, 0.2), (1987, 0.2), (1988, 0.2), (1989, 0.2), (1990, 0.2), (1991, 0.2), (1992, 0.2), (1993, 0.2), (1994, 0.2), (1995, 0.2), (1996, 0.2), (1997, 0.2), (1998, 0.2), (1999, 0.2), (2000, 0.2), (2001, 0.2), (2002, 0.2), (2003, 0.2), (2004, 0.2), (2005, 0.2), (2006, 0.2), (2007, 0.2), (2008, 0.2), (2009, 0.2), (2010, 0.2)

Livestock_index[Rabbit,Livestock_storaged_NH3] = GRAPH(TIME)

(1980, 0.1), (1981, 0.1), (1982, 0.1), (1983, 0.1), (1984, 0.1), (1985, 0.1), (1986, 0.1), (1987, 0.1), (1988, 0.1), (1989, 0.1), (1990, 0.1), (1991, 0.1), (1992, 0.1), (1993, 0.1), (1994, 0.1), (1995, 0.1), (1996, 0.1), (1997, 0.1), (1998, 0.1), (1999, 0.1), (2000, 0.1), (2001, 0.1), (2002, 0.1), (2003, 0.1), (2004, 0.1), (2005, 0.1), (2006, 0.1), (2007, 0.1), (2008, 0.1), (2009, 0.1), (2010, 0.1)

Livestock_index[Rabbit,Livestock_manure_NH3] = GRAPH(TIME)

(1980, 0.09), (1981, 0.09), (1982, 0.09), (1983, 0.09), (1984, 0.09), (1985, 0.09), (1986, 0.09), (1987, 0.09), (1988, 0.09), (1989, 0.09), (1990, 0.09), (1991, 0.09), (1992, 0.09), (1993, 0.09), (1994, 0.09), (1995, 0.09), (1996, 0.09), (1997, 0.09), (1998, 0.09), (1999, 0.09), (2000, 0.09), (2001, 0.09), (2002, 0.09), (2003, 0.09), (2004, 0.09), (2005, 0.09), (2006, 0.09), (2007, 0.09), (2008, 0.09), (2009, 0.09), (2010, 0.09)

Livestock_index[Rabbit,Livestock_material_production] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Rabbit,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Rabbit,Livestock_N_concen] = GRAPH(TIME)

(1980, 3.15), (1981, 3.15), (1982, 3.15), (1983, 3.15), (1984, 3.15), (1985, 3.15), (1986, 3.15), (1987, 3.15), (1988, 3.15), (1989, 3.15), (1990, 3.15), (1991, 3.15), (1992, 3.15), (1993, 3.15), (1994, 3.15), (1995, 3.15), (1996, 3.15), (1997, 3.15), (1998, 3.15), (1999, 3.15), (2000, 3.15), (2001, 3.15), (2002, 3.15), (2003, 3.15), (2004, 3.15), (2005, 3.15), (2006, 3.15), (2007, 3.15), (2008, 3.15), (2009, 3.15), (2010, 3.15)

Livestock_index[Rabbit,Livestock_numbers] = GRAPH(TIME)

(1980, 40000), (1981, 37000), (1982, 37000), (1983, 38000), (1984, 40000), (1985, 37400), (1986, 49000), (1987, 67000), (1988, 76650), (1989, 68650), (1990, 64000), (1991, 72000), (1992, 123000), (1993, 136000), (1994, 169246), (1995, 193928), (1996, 220000), (1997,

200000), (1998, 220000), (1999, 222000), (2000, 258782), (2001, 289925), (2002, 305602), (2003, 319384), (2004, 339859), (2005, 378404), (2006, 403677), (2007, 440873), (2008, 415299), (2009, 432814), (2010, 450000)

Livestock_index[Rabbit,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 1.00), (1981, 1.00), (1982, 1.00), (1983, 1.00), (1984, 1.00), (1985, 1.00), (1986, 1.00), (1987, 1.00), (1988, 1.00), (1989, 1.00), (1990, 1.00), (1991, 1.00), (1992, 1.00), (1993, 1.00), (1994, 1.00), (1995, 1.00), (1996, 1.00), (1997, 1.00), (1998, 1.00), (1999, 1.00), (2000, 1.00), (2001, 1.00), (2002, 1.00), (2003, 1.00), (2004, 1.00), (2005, 1.00), (2006, 1.00), (2007, 1.00), (2008, 1.00), (2009, 1.00), (2010, 1.00)

Livestock_index[Pig,Livestock_production] = GRAPH(TIME)

(1980, 1.2e+007), (1981, 1.2e+007), (1982, 1.3e+007), (1983, 1.3e+007), (1984, 1.5e+007), (1985, 1.7e+007), (1986, 1.7e+007), (1987, 1.9e+007), (1988, 2e+007), (1989, 2.1e+007), (1990, 2.3e+007), (1991, 2.4e+007), (1992, 2.6e+007), (1993, 2.7e+007), (1994, 2.9e+007), (1995, 3e+007), (1996, 3e+007), (1997, 3.1e+007), (1998, 3.3e+007), (1999, 3.4e+007), (2000, 3.6e+007), (2001, 3.6e+007), (2002, 3.7e+007), (2003, 3.9e+007), (2004, 3.9e+007), (2005, 4.1e+007), (2006, 4.3e+007), (2007, 4.3e+007), (2008, 4.5e+007), (2009, 4.7e+007), (2010, 4.9e+007)

Livestock_index[Pig,Livestock_excretion] = GRAPH(TIME)

(1980, 4.87), (1981, 4.87), (1982, 4.87), (1983, 4.87), (1984, 4.87), (1985, 4.87), (1986, 4.87), (1987, 4.87), (1988, 4.87), (1989, 4.87), (1990, 4.87), (1991, 4.87), (1992, 4.87), (1993, 4.87), (1994, 4.87), (1995, 4.87), (1996, 4.87), (1997, 4.87), (1998, 4.87), (1999, 4.87), (2000, 4.87), (2001, 4.87), (2002, 4.87), (2003, 4.87), (2004, 4.87), (2005, 4.87), (2006, 4.87), (2007, 4.87), (2008, 4.87), (2009, 4.87), (2010, 4.87)

Livestock_index[Pig,Livestock_total_NH3] = GRAPH(TIME)

(1980, 2.33), (1981, 2.33), (1982, 2.33), (1983, 2.33), (1984, 2.33), (1985, 2.33), (1986, 2.33), (1987, 2.33), (1988, 2.33), (1989, 2.33), (1990, 2.33), (1991, 2.33), (1992, 2.33), (1993, 2.33), (1994, 2.33), (1995, 2.33), (1996, 2.33), (1997, 2.33), (1998, 2.33), (1999, 2.33), (2000, 2.33), (2001, 2.33), (2002, 2.33), (2003, 2.33), (2004, 2.33), (2005, 2.33), (2006, 2.33), (2007, 2.33), (2008, 2.33), (2009, 2.33), (2010, 2.33)

Livestock_index[Pig,Livestock_storaged_NH3] = GRAPH(TIME)

(1980, 1.43), (1981, 1.43), (1982, 1.43), (1983, 1.43), (1984, 1.43), (1985, 1.43), (1986, 1.43), (1987, 1.43), (1988, 1.43), (1989, 1.43), (1990, 1.43), (1991, 1.43), (1992, 1.43), (1993, 1.43), (1994, 1.43), (1995, 1.43), (1996, 1.43), (1997, 1.43), (1998, 1.43), (1999, 1.43), (2000, 1.43), (2001, 1.43), (2002, 1.43), (2003, 1.43), (2004, 1.43), (2005, 1.43), (2006, 1.43), (2007, 1.43), (2008, 1.43), (2009, 1.43), (2010, 1.43)

Livestock_index[Pig,Livestock_manure_NH3] = GRAPH(TIME)

(1980, 0.9), (1981, 0.9), (1982, 0.9), (1983, 0.9), (1984, 0.9), (1985, 0.9), (1986, 0.9), (1987, 0.9), (1988, 0.9), (1989, 0.9), (1990, 0.9), (1991, 0.9), (1992, 0.9), (1993, 0.9), (1994, 0.9), (1995, 0.9), (1996, 0.9), (1997, 0.9), (1998, 0.9), (1999, 0.9), (2000, 0.9), (2001, 0.9), (2002, 0.9), (2003, 0.9), (2004, 0.9), (2005, 0.9), (2006, 0.9), (2007, 0.9), (2008, 0.9), (2009, 0.9), (2010, 0.9)

Livestock_index[Pig,Livestock_material_production] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00),

(1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Pig,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Pig,Livestock_N_concen] = GRAPH(TIME)

(1980, 2.11), (1981, 2.11), (1982, 2.11), (1983, 2.11), (1984, 2.11), (1985, 2.11), (1986, 2.11), (1987, 2.11), (1988, 2.11), (1989, 2.11), (1990, 2.11), (1991, 2.11), (1992, 2.11), (1993, 2.11), (1994, 2.11), (1995, 2.11), (1996, 2.11), (1997, 2.11), (1998, 2.11), (1999, 2.11), (2000, 2.11), (2001, 2.11), (2002, 2.11), (2003, 2.11), (2004, 2.11), (2005, 2.11), (2006, 2.11), (2007, 2.11), (2008, 2.11), (2009, 2.11), (2010, 2.11)

Livestock_index[Pig,Livestock_numbers] = GRAPH(TIME)

(1980, 319705), (1981, 305431), (1982, 293700), (1983, 300780), (1984, 298536), (1985, 306792), (1986, 331396), (1987, 337191), (1988, 324456), (1989, 338796), (1990, 345755), (1991, 351538), (1992, 354860), (1993, 357316), (1994, 361561), (1995, 360715), (1996, 364720), (1997, 362836), (1998, 368320), (1999, 380307), (2000, 388298), (2001, 387193), (2002, 390140), (2003, 392696), (2004, 393127), (2005, 400173), (2006, 411532), (2007, 418504), (2008, 426698), (2009, 444397), (2010, 469967)

Livestock_index[Pig,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Cow,Livestock_production] = GRAPH(TIME)

(1980, 257297), (1981, 257124), (1982, 261475), (1983, 280272), (1984, 318969), (1985, 363964), (1986, 469395), (1987, 671441), (1988, 780110), (1989, 935971), (1990, 1.1e+006), (1991, 1.3e+006), (1992, 1.6e+006), (1993, 2e+006), (1994, 2.1e+006), (1995, 2.6e+006), (1996, 3e+006), (1997, 3.6e+006), (1998, 4e+006), (1999, 4.2e+006), (2000, 4.6e+006), (2001, 4.7e+006), (2002, 4.8e+006), (2003, 5.1e+006), (2004, 5.3e+006), (2005, 5.3e+006), (2006, 5.5e+006), (2007, 5.8e+006), (2008, 5.8e+006), (2009, 6e+006), (2010, 6.2e+006)

Livestock_index[Cow,Livestock_excretion] = GRAPH(TIME)

(1980, 56.8), (1981, 56.8), (1982, 56.8), (1983, 56.8), (1984, 56.8), (1985, 56.8), (1986, 56.8), (1987, 56.8), (1988, 56.8), (1989, 56.8), (1990, 56.8), (1991, 56.8), (1992, 56.8), (1993, 56.8), (1994, 56.8), (1995, 56.8), (1996, 56.8), (1997, 56.8), (1998, 56.8), (1999, 56.8), (2000, 56.8), (2001, 56.8), (2002, 56.8), (2003, 56.8), (2004, 56.8), (2005, 56.8), (2006, 56.8), (2007, 56.8), (2008, 56.8), (2009, 56.8), (2010, 56.8)

Livestock_index[Cow,Livestock_total_NH3] = GRAPH(TIME)
(1980, 22.0), (1981, 22.0), (1982, 22.0), (1983, 22.0), (1984, 22.0), (1985, 22.0), (1986, 22.0), (1987, 22.0), (1988, 22.0), (1989, 22.0), (1990, 22.0), (1991, 22.0), (1992, 22.0), (1993, 22.0), (1994, 22.0), (1995, 22.0), (1996, 22.0), (1997, 22.0), (1998, 22.0), (1999, 22.0), (2000, 22.0), (2001, 22.0), (2002, 22.0), (2003, 22.0), (2004, 22.0), (2005, 22.0), (2006, 22.0), (2007, 22.0), (2008, 22.0), (2009, 22.0), (2010, 22.0)
Livestock_index[Cow,Livestock_storaged_NH3] = GRAPH(TIME)
(1980, 10.6), (1981, 10.6), (1982, 10.6), (1983, 10.6), (1984, 10.6), (1985, 10.6), (1986, 10.6), (1987, 10.6), (1988, 10.6), (1989, 10.6), (1990, 10.6), (1991, 10.6), (1992, 10.6), (1993, 10.6), (1994, 10.6), (1995, 10.6), (1996, 10.6), (1997, 10.6), (1998, 10.6), (1999, 10.6), (2000, 10.6), (2001, 10.6), (2002, 10.6), (2003, 10.6), (2004, 10.6), (2005, 10.6), (2006, 10.6), (2007, 10.6), (2008, 10.6), (2009, 10.6), (2010, 10.6)
Livestock_index[Cow,Livestock_manure_NH3] = GRAPH(TIME)
(1980, 11.2), (1981, 11.2), (1982, 11.2), (1983, 11.2), (1984, 11.2), (1985, 11.2), (1986, 11.2), (1987, 11.2), (1988, 11.2), (1989, 11.2), (1990, 11.2), (1991, 11.2), (1992, 11.2), (1993, 11.2), (1994, 11.2), (1995, 11.2), (1996, 11.2), (1997, 11.2), (1998, 11.2), (1999, 11.2), (2000, 11.2), (2001, 11.2), (2002, 11.2), (2003, 11.2), (2004, 11.2), (2005, 11.2), (2006, 11.2), (2007, 11.2), (2008, 11.2), (2009, 11.2), (2010, 11.2)
Livestock_index[Cow,Livestock_material_production] = GRAPH(TIME)
(1980, 62250), (1981, 61500), (1982, 65000), (1983, 69160), (1984, 79560), (1985, 89700), (1986, 123200), (1987, 145600), (1988, 160776), (1989, 189486), (1990, 226380), (1991, 270630), (1992, 319488), (1993, 405108), (1994, 539386), (1995, 623696), (1996, 697680), (1997, 894125), (1998, 993723), (1999, 1e+006), (2000, 1.1e+006), (2001, 1.1e+006), (2002, 1.2e+006), (2003, 1.2e+006), (2004, 1.3e+006), (2005, 1.3e+006), (2006, 1.3e+006), (2007, 1.4e+006), (2008, 1.4e+006), (2009, 1.5e+006), (2010, 1.5e+006)
Livestock_index[Cow,Livestock_material_N_concen] = GRAPH(TIME)
(1980, 12.6), (1981, 12.6), (1982, 12.6), (1983, 12.6), (1984, 12.6), (1985, 12.6), (1986, 12.6), (1987, 12.6), (1988, 12.6), (1989, 12.6), (1990, 12.6), (1991, 12.6), (1992, 12.6), (1993, 12.6), (1994, 12.6), (1995, 12.6), (1996, 12.6), (1997, 12.6), (1998, 12.6), (1999, 12.6), (2000, 12.6), (2001, 12.6), (2002, 12.6), (2003, 12.6), (2004, 12.6), (2005, 12.6), (2006, 12.6), (2007, 12.6), (2008, 12.6), (2009, 12.6), (2010, 12.6)
Livestock_index[Cow,Livestock_N_concen] = GRAPH(TIME)
(1980, 3.18), (1981, 3.18), (1982, 3.18), (1983, 3.18), (1984, 3.18), (1985, 3.18), (1986, 3.18), (1987, 3.18), (1988, 3.18), (1989, 3.18), (1990, 3.18), (1991, 3.18), (1992, 3.18), (1993, 3.18), (1994, 3.18), (1995, 3.18), (1996, 3.18), (1997, 3.18), (1998, 3.18), (1999, 3.18), (2000, 3.18), (2001, 3.18), (2002, 3.18), (2003, 3.18), (2004, 3.18), (2005, 3.18), (2006, 3.18), (2007, 3.18), (2008, 3.18), (2009, 3.18), (2010, 3.18)
Livestock_index[Cow,Livestock_numbers] = GRAPH(TIME)
(1980, 52411), (1981, 52515), (1982, 53833), (1983, 56926), (1984, 58935), (1985, 62622), (1986, 66886), (1987, 70847), (1988, 73089), (1989, 76114), (1990, 77770), (1991, 78758), (1992, 79284), (1993, 79645), (1994, 83497), (1995, 87352), (1996, 89375), (1997, 90682), (1998, 91355), (1999, 91579), (2000, 93956), (2001, 98492), (2002, 98169), (2003, 101636),

(2004, 106770), (2005, 109684), (2006, 113126), (2007, 116725), (2008, 117996), (2009, 119420), (2010, 121300)

Livestock_index[Cow,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 0.51), (1981, 0.51), (1982, 0.51), (1983, 0.51), (1984, 0.51), (1985, 0.51), (1986, 0.51), (1987, 0.51), (1988, 0.51), (1989, 0.51), (1990, 0.51), (1991, 0.51), (1992, 0.51), (1993, 0.51), (1994, 0.51), (1995, 0.51), (1996, 0.51), (1997, 0.51), (1998, 0.51), (1999, 0.51), (2000, 0.51), (2001, 0.51), (2002, 0.51), (2003, 0.51), (2004, 0.51), (2005, 0.51), (2006, 0.51), (2007, 0.51), (2008, 0.51), (2009, 0.51), (2010, 0.51)

Livestock_index[Sheep\Goat,Livestock_production] = GRAPH(TIME)

(1980, 449835), (1981, 474541), (1982, 522984), (1983, 544622), (1984, 586963), (1985, 594276), (1986, 623300), (1987, 721370), (1988, 802672), (1989, 962098), (1990, 1.1e+006), (1991, 1.2e+006), (1992, 1.3e+006), (1993, 1.4e+006), (1994, 1.5e+006), (1995, 1.7e+006), (1996, 1.8e+006), (1997, 2.1e+006), (1998, 2.4e+006), (1999, 2.5e+006), (2000, 2.6e+006), (2001, 2.7e+006), (2002, 2.8e+006), (2003, 3e+006), (2004, 3.3e+006), (2005, 3.4e+006), (2006, 3.6e+006), (2007, 3.8e+006), (2008, 3.7e+006), (2009, 3.8e+006), (2010, 4e+006)

Livestock_index[Sheep\Goat,Livestock_excretion] = GRAPH(TIME)

(1980, 11.2), (1981, 11.2), (1982, 11.2), (1983, 11.2), (1984, 11.2), (1985, 11.2), (1986, 11.2), (1987, 11.2), (1988, 11.2), (1989, 11.2), (1990, 11.2), (1991, 11.2), (1992, 11.2), (1993, 11.2), (1994, 11.2), (1995, 11.2), (1996, 11.2), (1997, 11.2), (1998, 11.2), (1999, 11.2), (2000, 11.2), (2001, 11.2), (2002, 11.2), (2003, 11.2), (2004, 11.2), (2005, 11.2), (2006, 11.2), (2007, 11.2), (2008, 11.2), (2009, 11.2), (2010, 11.2)

Livestock_index[Sheep\Goat,Livestock_total_NH3] = GRAPH(TIME)

(1980, 4.18), (1981, 4.18), (1982, 4.18), (1983, 4.18), (1984, 4.18), (1985, 4.18), (1986, 4.18), (1987, 4.18), (1988, 4.18), (1989, 4.18), (1990, 4.18), (1991, 4.18), (1992, 4.18), (1993, 4.18), (1994, 4.18), (1995, 4.18), (1996, 4.18), (1997, 4.18), (1998, 4.18), (1999, 4.18), (2000, 4.18), (2001, 4.18), (2002, 4.18), (2003, 4.18), (2004, 4.18), (2005, 4.18), (2006, 4.18), (2007, 4.18), (2008, 4.18), (2009, 4.18), (2010, 4.18)

Livestock_index[Sheep\Goat,Livestock_storaged_NH3] = GRAPH(TIME)

(1980, 0.63), (1981, 0.63), (1982, 0.63), (1983, 0.63), (1984, 0.63), (1985, 0.63), (1986, 0.63), (1987, 0.63), (1988, 0.63), (1989, 0.63), (1990, 0.63), (1991, 0.63), (1992, 0.63), (1993, 0.63), (1994, 0.63), (1995, 0.63), (1996, 0.63), (1997, 0.63), (1998, 0.63), (1999, 0.63), (2000, 0.63), (2001, 0.63), (2002, 0.63), (2003, 0.63), (2004, 0.63), (2005, 0.63), (2006, 0.63), (2007, 0.63), (2008, 0.63), (2009, 0.63), (2010, 0.63)

Livestock_index[Sheep\Goat,Livestock_manure_NH3] = GRAPH(TIME)

(1980, 2.95), (1981, 2.95), (1982, 2.95), (1983, 2.95), (1984, 2.95), (1985, 2.95), (1986, 2.95), (1987, 2.95), (1988, 2.95), (1989, 2.95), (1990, 2.95), (1991, 2.95), (1992, 2.95), (1993, 2.95), (1994, 2.95), (1995, 2.95), (1996, 2.95), (1997, 2.95), (1998, 2.95), (1999, 2.95), (2000, 2.95), (2001, 2.95), (2002, 2.95), (2003, 2.95), (2004, 2.95), (2005, 2.95), (2006, 2.95), (2007, 2.95), (2008, 2.95), (2009, 2.95), (2010, 2.95)

Livestock_index[Sheep\Goat,Livestock_material_production] = GRAPH(TIME)

(1980, 285376), (1981, 303950), (1982, 323500), (1983, 316620), (1984, 311657), (1985, 307616), (1986, 328832), (1987, 375277), (1988, 408608), (1989, 459639), (1990, 483567),

(1991, 507360), (1992, 521826), (1993, 545912), (1994, 582869), (1995, 663357), (1996, 680224), (1997, 694143), (1998, 752000), (1999, 800473), (2000, 836880), (2001, 842442), (2002, 873053), (2003, 951550), (2004, 1e+006), (2005, 1.1e+006), (2006, 1.1e+006), (2007, 1.1e+006), (2008, 1.1e+006), (2009, 1.1e+006), (2010, 1.2e+006)

Livestock_index[Sheep\Goat,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 10.3), (1981, 10.3), (1982, 10.3), (1983, 10.3), (1984, 10.3), (1985, 10.3), (1986, 10.3), (1987, 10.3), (1988, 10.3), (1989, 10.3), (1990, 10.3), (1991, 10.3), (1992, 10.3), (1993, 10.3), (1994, 10.3), (1995, 10.3), (1996, 10.3), (1997, 10.3), (1998, 10.3), (1999, 10.3), (2000, 10.3), (2001, 10.3), (2002, 10.3), (2003, 10.3), (2004, 10.3), (2005, 10.3), (2006, 10.3), (2007, 10.3), (2008, 10.3), (2009, 10.3), (2010, 10.3)

Livestock_index[Sheep\Goat,Livestock_N_concen] = GRAPH(TIME)

(1980, 3.04), (1981, 3.04), (1982, 3.04), (1983, 3.04), (1984, 3.04), (1985, 3.04), (1986, 3.04), (1987, 3.04), (1988, 3.04), (1989, 3.04), (1990, 3.04), (1991, 3.04), (1992, 3.04), (1993, 3.04), (1994, 3.04), (1995, 3.04), (1996, 3.04), (1997, 3.04), (1998, 3.04), (1999, 3.04), (2000, 3.04), (2001, 3.04), (2002, 3.04), (2003, 3.04), (2004, 3.04), (2005, 3.04), (2006, 3.04), (2007, 3.04), (2008, 3.04), (2009, 3.04), (2010, 3.04)

Livestock_index[Sheep\Goat,Livestock_numbers] = GRAPH(TIME)

(1980, 183142), (1981, 187311), (1982, 187730), (1983, 181790), (1984, 166955), (1985, 158400), (1986, 155884), (1987, 166229), (1988, 178539), (1989, 199512), (1990, 207409), (1991, 205821), (1992, 202086), (1993, 203183), (1994, 213027), (1995, 233313), (1996, 240525), (1997, 237283), (1998, 255757), (1999, 269035), (2000, 279258), (2001, 290319), (2002, 298263), (2003, 316552), (2004, 340511), (2005, 366400), (2006, 372659), (2007, 368966), (2008, 367895), (2009, 369537), (2010, 372550)

Livestock_index[Sheep\Goat,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 0.6), (1981, 0.6), (1982, 0.6), (1983, 0.6), (1984, 0.6), (1985, 0.6), (1986, 0.6), (1987, 0.6), (1988, 0.6), (1989, 0.6), (1990, 0.6), (1991, 0.6), (1992, 0.6), (1993, 0.6), (1994, 0.6), (1995, 0.6), (1996, 0.6), (1997, 0.6), (1998, 0.6), (1999, 0.6), (2000, 0.6), (2001, 0.6), (2002, 0.6), (2003, 0.6), (2004, 0.6), (2005, 0.6), (2006, 0.6), (2007, 0.6), (2008, 0.6), (2009, 0.6), (2010, 0.6)

Livestock_index[Horse\Donkey\Mule,Livestock_production] = GRAPH(TIME)

(1980, 70680), (1981, 72840), (1982, 74480), (1983, 77800), (1984, 79800), (1985, 84260), (1986, 89200), (1987, 96305), (1988, 98925), (1989, 102882), (1990, 106463), (1991, 111928), (1992, 252353), (1993, 245314), (1994, 318087), (1995, 346495), (1996, 401410), (1997, 362364), (1998, 374955), (1999, 377913), (2000, 401960), (2001, 415009), (2002, 413500), (2003, 423415), (2004, 424996), (2005, 421842), (2006, 424323), (2007, 412304), (2008, 396171), (2009, 413203), (2010, 403048)

Livestock_index[Horse\Donkey\Mule,Livestock_excretion] = GRAPH(TIME)

(1980, 68.6), (1981, 68.6), (1982, 68.6), (1983, 68.6), (1984, 68.6), (1985, 68.6), (1986, 68.6), (1987, 68.6), (1988, 68.6), (1989, 68.6), (1990, 68.6), (1991, 68.6), (1992, 68.6), (1993, 68.6), (1994, 68.6), (1995, 68.6), (1996, 68.6), (1997, 68.6), (1998, 68.6), (1999, 68.6), (2000, 68.6), (2001, 68.6), (2002, 68.6), (2003, 68.6), (2004, 68.6), (2005, 68.6), (2006, 68.6), (2007, 68.6), (2008, 68.6), (2009, 68.6), (2010, 68.6)

Livestock_index[Horse\Donkey\Mule,Livestock_total_NH3] = GRAPH(TIME)

(1980, 18.6), (1981, 18.6), (1982, 18.6), (1983, 18.6), (1984, 18.6), (1985, 18.6), (1986, 18.6), (1987, 18.6), (1988, 18.6), (1989, 18.6), (1990, 18.6), (1991, 18.6), (1992, 18.6), (1993, 18.6), (1994, 18.6), (1995, 18.6), (1996, 18.6), (1997, 18.6), (1998, 18.6), (1999, 18.6), (2000, 18.6), (2001, 18.6), (2002, 18.6), (2003, 18.6), (2004, 18.6), (2005, 18.6), (2006, 18.6), (2007, 18.6), (2008, 18.6), (2009, 18.6), (2010, 18.6)

Livestock_index[Horse\Donkey\Mule,Livestock_storaged_NH3] = GRAPH(TIME)

(1980, 6.11), (1981, 6.11), (1982, 6.11), (1983, 6.11), (1984, 6.11), (1985, 6.11), (1986, 6.11), (1987, 6.11), (1988, 6.11), (1989, 6.11), (1990, 6.11), (1991, 6.11), (1992, 6.11), (1993, 6.11), (1994, 6.11), (1995, 6.11), (1996, 6.11), (1997, 6.11), (1998, 6.11), (1999, 6.11), (2000, 6.11), (2001, 6.11), (2002, 6.11), (2003, 6.11), (2004, 6.11), (2005, 6.11), (2006, 6.11), (2007, 6.11), (2008, 6.11), (2009, 6.11), (2010, 6.11)

Livestock_index[Horse\Donkey\Mule,Livestock_manure_NH3] = GRAPH(TIME)

(1980, 7.50), (1981, 7.50), (1982, 7.50), (1983, 7.50), (1984, 7.50), (1985, 7.50), (1986, 7.50), (1987, 7.50), (1988, 7.50), (1989, 7.50), (1990, 7.50), (1991, 7.50), (1992, 7.50), (1993, 7.50), (1994, 7.50), (1995, 7.50), (1996, 7.50), (1997, 7.50), (1998, 7.50), (1999, 7.50), (2000, 7.50), (2001, 7.50), (2002, 7.50), (2003, 7.50), (2004, 7.50), (2005, 7.50), (2006, 7.50), (2007, 7.50), (2008, 7.50), (2009, 7.50), (2010, 7.50)

Livestock_index[Horse\Donkey\Mule,Livestock_material_production] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Horse\Donkey\Mule,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Horse\Donkey\Mule,Livestock_N_concen] = GRAPH(TIME)

(1980, 3.33), (1981, 3.33), (1982, 3.33), (1983, 3.33), (1984, 3.33), (1985, 3.33), (1986, 3.33), (1987, 3.33), (1988, 3.33), (1989, 3.33), (1990, 3.33), (1991, 3.33), (1992, 3.33), (1993, 3.33), (1994, 3.33), (1995, 3.33), (1996, 3.33), (1997, 3.33), (1998, 3.33), (1999, 3.33), (2000, 3.33), (2001, 3.33), (2002, 3.33), (2003, 3.33), (2004, 3.33), (2005, 3.33), (2006, 3.33), (2007, 3.33), (2008, 3.33), (2009, 3.33), (2010, 3.33)

Livestock_index[Horse\Donkey\Mule,Livestock_numbers] = GRAPH(TIME)

(1980, 22641), (1981, 22956), (1982, 23712), (1983, 24444), (1984, 24848), (1985, 25730), (1986, 26468), (1987, 26790), (1988, 26785), (1989, 26958), (1990, 26821), (1991, 26866), (1992, 26858), (1993, 26610), (1994, 26348), (1995, 26512), (1996, 26206), (1997, 22939), (1998, 23246), (1999, 23278), (2000, 22935), (2001, 22523), (2002, 21437), (2003, 20781), (2004, 20064), (2005, 19298), (2006, 18776), (2007, 17952), (2008, 16904), (2009, 16507), (2010, 16062)

Livestock_index[Horse\Donkey\Mule,Livestock_grassland_ratio] = GRAPH(TIME)
(1980, 0.74), (1981, 0.74), (1982, 0.74), (1983, 0.74), (1984, 0.74), (1985, 0.74), (1986, 0.74),
(1987, 0.74), (1988, 0.74), (1989, 0.74), (1990, 0.74), (1991, 0.74), (1992, 0.74), (1993, 0.74),
(1994, 0.74), (1995, 0.74), (1996, 0.74), (1997, 0.74), (1998, 0.74), (1999, 0.74), (2000, 0.74),
(2001, 0.74), (2002, 0.74), (2003, 0.74), (2004, 0.74), (2005, 0.74), (2006, 0.74), (2007, 0.74),
(2008, 0.74), (2009, 0.74), (2010, 0.74)
Livestock_index[Camel,Livestock_production] = GRAPH(TIME)
(1980, 11000), (1981, 12100), (1982, 13200), (1983, 12980), (1984, 13640), (1985, 14300),
(1986, 14960), (1987, 15400), (1988, 15840), (1989, 16500), (1990, 17160), (1991, 7040), (1992,
9020), (1993, 10010), (1994, 11682), (1995, 11000), (1996, 10340), (1997, 10560), (1998,
13420), (1999, 14740), (2000, 14740), (2001, 18700), (2002, 15180), (2003, 14300), (2004,
14432), (2005, 14388), (2006, 14960), (2007, 16280), (2008, 17820), (2009, 13860), (2010,
14300)
Livestock_index[Camel,Livestock_excretion] = GRAPH(TIME)
(1980, 55.0), (1981, 55.0), (1982, 55.0), (1983, 55.0), (1984, 55.0), (1985, 55.0), (1986, 55.0),
(1987, 55.0), (1988, 55.0), (1989, 55.0), (1990, 55.0), (1991, 55.0), (1992, 55.0), (1993, 55.0),
(1994, 55.0), (1995, 55.0), (1996, 55.0), (1997, 55.0), (1998, 55.0), (1999, 55.0), (2000, 55.0),
(2001, 55.0), (2002, 55.0), (2003, 55.0), (2004, 55.0), (2005, 55.0), (2006, 55.0), (2007, 55.0),
(2008, 55.0), (2009, 55.0), (2010, 55.0)
Livestock_index[Camel,Livestock_total_NH3] = GRAPH(TIME)
(1980, 10.5), (1981, 10.5), (1982, 10.5), (1983, 10.5), (1984, 10.5), (1985, 10.5), (1986, 10.5),
(1987, 10.5), (1988, 10.5), (1989, 10.5), (1990, 10.5), (1991, 10.5), (1992, 10.5), (1993, 10.5),
(1994, 10.5), (1995, 10.5), (1996, 10.5), (1997, 10.5), (1998, 10.5), (1999, 10.5), (2000, 10.5),
(2001, 10.5), (2002, 10.5), (2003, 10.5), (2004, 10.5), (2005, 10.5), (2006, 10.5), (2007, 10.5),
(2008, 10.5), (2009, 10.5), (2010, 10.5)
Livestock_index[Camel,Livestock_storaged_NH3] = GRAPH(TIME)
(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00),
(1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00),
(1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00),
(2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00),
(2008, 0.00), (2009, 0.00), (2010, 0.00)
Livestock_index[Camel,Livestock_manure_NH3] = GRAPH(TIME)
(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00),
(1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00),
(1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00),
(2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00),
(2008, 0.00), (2009, 0.00), (2010, 0.00)
Livestock_index[Camel,Livestock_material_production] = GRAPH(TIME)
(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00),
(1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00),
(1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00),
(2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00),

(2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Camel,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Camel,Livestock_N_concen] = GRAPH(TIME)

(1980, 3.33), (1981, 3.33), (1982, 3.33), (1983, 3.33), (1984, 3.33), (1985, 3.33), (1986, 3.33), (1987, 3.33), (1988, 3.33), (1989, 3.33), (1990, 3.33), (1991, 3.33), (1992, 3.33), (1993, 3.33), (1994, 3.33), (1995, 3.33), (1996, 3.33), (1997, 3.33), (1998, 3.33), (1999, 3.33), (2000, 3.33), (2001, 3.33), (2002, 3.33), (2003, 3.33), (2004, 3.33), (2005, 3.33), (2006, 3.33), (2007, 3.33), (2008, 3.33), (2009, 3.33), (2010, 3.33)

Livestock_index[Camel,Livestock_numbers] = GRAPH(TIME)

(1980, 604), (1981, 614), (1982, 628), (1983, 610), (1984, 564), (1985, 531), (1986, 530), (1987, 504), (1988, 475), (1989, 472), (1990, 475), (1991, 463), (1992, 441), (1993, 401), (1994, 373), (1995, 356), (1996, 351), (1997, 349), (1998, 350), (1999, 335), (2000, 330), (2001, 326), (2002, 279), (2003, 264), (2004, 265), (2005, 262), (2006, 266), (2007, 269), (2008, 242), (2009, 240), (2010, 248)

Livestock_index[Camel,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 1.00), (1981, 1.00), (1982, 1.00), (1983, 1.00), (1984, 1.00), (1985, 1.00), (1986, 1.00), (1987, 1.00), (1988, 1.00), (1989, 1.00), (1990, 1.00), (1991, 1.00), (1992, 1.00), (1993, 1.00), (1994, 1.00), (1995, 1.00), (1996, 1.00), (1997, 1.00), (1998, 1.00), (1999, 1.00), (2000, 1.00), (2001, 1.00), (2002, 1.00), (2003, 1.00), (2004, 1.00), (2005, 1.00), (2006, 1.00), (2007, 1.00), (2008, 1.00), (2009, 1.00), (2010, 1.00)

Livestock_index[Eggs,Livestock_production] = GRAPH(TIME)

(1980, 2.8e+006), (1981, 2.9e+006), (1982, 3.1e+006), (1983, 3.3e+006), (1984, 4.3e+006), (1985, 5.3e+006), (1986, 5.6e+006), (1987, 5.9e+006), (1988, 7e+006), (1989, 7.2e+006), (1990, 7.9e+006), (1991, 9.2e+006), (1992, 1e+007), (1993, 1.2e+007), (1994, 1.5e+007), (1995, 1.7e+007), (1996, 2e+007), (1997, 1.9e+007), (1998, 2e+007), (1999, 2.1e+007), (2000, 2.2e+007), (2001, 2.2e+007), (2002, 2.3e+007), (2003, 2.3e+007), (2004, 2.4e+007), (2005, 2.4e+007), (2006, 2.4e+007), (2007, 2.5e+007), (2008, 2.7e+007), (2009, 2.7e+007), (2010, 2.8e+007)

Livestock_index[Eggs,Livestock_excretion] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Eggs,Livestock_total_NH3] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00),

(1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Eggs,Livestock_storaged_NH3] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Eggs,Livestock_manure_NH3] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Eggs,Livestock_material_production] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Eggs,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Eggs,Livestock_N_concen] = GRAPH(TIME)

(1980, 2.08), (1981, 2.08), (1982, 2.08), (1983, 2.08), (1984, 2.08), (1985, 2.08), (1986, 2.08), (1987, 2.08), (1988, 2.08), (1989, 2.08), (1990, 2.08), (1991, 2.08), (1992, 2.08), (1993, 2.08), (1994, 2.08), (1995, 2.08), (1996, 2.08), (1997, 2.08), (1998, 2.08), (1999, 2.08), (2000, 2.08), (2001, 2.08), (2002, 2.08), (2003, 2.08), (2004, 2.08), (2005, 2.08), (2006, 2.08), (2007, 2.08), (2008, 2.08), (2009, 2.08), (2010, 2.08)

Livestock_index[Eggs,Livestock_numbers] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Eggs,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00),

(1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Milk,Livestock_production] = GRAPH(TIME)

(1980, 2.9e+006), (1981, 3.1e+006), (1982, 3.5e+006), (1983, 3.9e+006), (1984, 4.3e+006), (1985, 4.7e+006), (1986, 5.2e+006), (1987, 5.7e+006), (1988, 6.2e+006), (1989, 6.4e+006), (1990, 6.8e+006), (1991, 7.4e+006), (1992, 7.8e+006), (1993, 7.9e+006), (1994, 8.4e+006), (1995, 9.1e+006), (1996, 9.8e+006), (1997, 9.7e+006), (1998, 1e+007), (1999, 1.1e+007), (2000, 1.2e+007), (2001, 1.4e+007), (2002, 1.7e+007), (2003, 2.2e+007), (2004, 2.7e+007), (2005, 3.2e+007), (2006, 3.6e+007), (2007, 3.9e+007), (2008, 4e+007), (2009, 4e+007), (2010, 4.1e+007)

Livestock_index[Milk,Livestock_excretion] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Milk,Livestock_total_NH3] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Milk,Livestock_storaged_NH3] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Milk,Livestock_manure_NH3] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Milk,Livestock_material_production] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Milk,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Milk,Livestock_N_concen] = GRAPH(TIME)

(1980, 0.36), (1981, 0.36), (1982, 0.36), (1983, 0.36), (1984, 0.36), (1985, 0.36), (1986, 0.36), (1987, 0.36), (1988, 0.36), (1989, 0.36), (1990, 0.36), (1991, 0.36), (1992, 0.36), (1993, 0.36), (1994, 0.36), (1995, 0.36), (1996, 0.36), (1997, 0.36), (1998, 0.36), (1999, 0.36), (2000, 0.36), (2001, 0.36), (2002, 0.36), (2003, 0.36), (2004, 0.36), (2005, 0.36), (2006, 0.36), (2007, 0.36), (2008, 0.36), (2009, 0.36), (2010, 0.36)

Livestock_index[Milk,Livestock_numbers] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Milk,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00), (1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Livestock_index[Buffalo,Livestock_production] = GRAPH(TIME)

(1980, 2.9e+006), (1981, 3.1e+006), (1982, 3.5e+006), (1983, 3.9e+006), (1984, 4.3e+006), (1985, 4.7e+006), (1986, 5.2e+006), (1987, 5.7e+006), (1988, 6.2e+006), (1989, 6.4e+006), (1990, 6.8e+006), (1991, 7.4e+006), (1992, 7.8e+006), (1993, 7.9e+006), (1994, 8.4e+006), (1995, 9.1e+006), (1996, 9.8e+006), (1997, 9.7e+006), (1998, 1e+007), (1999, 1.1e+007), (2000, 1.2e+007), (2001, 1.4e+007), (2002, 1.7e+007), (2003, 2.2e+007), (2004, 2.7e+007), (2005, 3.2e+007), (2006, 3.6e+007), (2007, 3.9e+007), (2008, 4e+007), (2009, 4e+007), (2010, 4.1e+007)

Livestock_index[Buffalo,Livestock_excretion] = GRAPH(TIME)

(1980, 45.0), (1981, 45.0), (1982, 45.0), (1983, 45.0), (1984, 45.0), (1985, 45.0), (1986, 45.0), (1987, 45.0), (1988, 45.0), (1989, 45.0), (1990, 45.0), (1991, 45.0), (1992, 45.0), (1993, 45.0), (1994, 45.0), (1995, 45.0), (1996, 45.0), (1997, 45.0), (1998, 45.0), (1999, 45.0), (2000, 45.0), (2001, 45.0), (2002, 45.0), (2003, 45.0), (2004, 45.0), (2005, 45.0), (2006, 45.0), (2007, 45.0), (2008, 45.0), (2009, 45.0), (2010, 45.0)

Livestock_index[Buffalo,Livestock_total_NH3] = GRAPH(TIME)

(1980, 8.70), (1981, 8.70), (1982, 8.70), (1983, 8.70), (1984, 8.70), (1985, 8.70), (1986, 8.70), (1987, 8.70), (1988, 8.70), (1989, 8.70), (1990, 8.70), (1991, 8.70), (1992, 8.70), (1993, 8.70), (1994, 8.70), (1995, 8.70), (1996, 8.70), (1997, 8.70), (1998, 8.70), (1999, 8.70), (2000, 8.70), (2001, 8.70), (2002, 8.70), (2003, 8.70), (2004, 8.70), (2005, 8.70), (2006, 8.70), (2007, 8.70),

(2008, 8.70), (2009, 8.70), (2010, 8.70)

Livestock_index[Buffalo,Livestock_storaged_NH3] = GRAPH(TIME)

(1980, 4.35), (1981, 4.35), (1982, 4.35), (1983, 4.35), (1984, 4.35), (1985, 4.35), (1986, 4.35), (1987, 4.35), (1988, 4.35), (1989, 4.35), (1990, 4.35), (1991, 4.35), (1992, 4.35), (1993, 4.35), (1994, 4.35), (1995, 4.35), (1996, 4.35), (1997, 4.35), (1998, 4.35), (1999, 4.35), (2000, 4.35), (2001, 4.35), (2002, 4.35), (2003, 4.35), (2004, 4.35), (2005, 4.35), (2006, 4.35), (2007, 4.35), (2008, 4.35), (2009, 4.35), (2010, 4.35)

Livestock_index[Buffalo,Livestock_manure_NH3] = GRAPH(TIME)

(1980, 4.35), (1981, 4.35), (1982, 4.35), (1983, 4.35), (1984, 4.35), (1985, 4.35), (1986, 4.35), (1987, 4.35), (1988, 4.35), (1989, 4.35), (1990, 4.35), (1991, 4.35), (1992, 4.35), (1993, 4.35), (1994, 4.35), (1995, 4.35), (1996, 4.35), (1997, 4.35), (1998, 4.35), (1999, 4.35), (2000, 4.35), (2001, 4.35), (2002, 4.35), (2003, 4.35), (2004, 4.35), (2005, 4.35), (2006, 4.35), (2007, 4.35), (2008, 4.35), (2009, 4.35), (2010, 4.35)

Livestock_index[Buffalo,Livestock_material_production] = GRAPH(TIME)

(1980, 22500), (1981, 22875), (1982, 23475), (1983, 27750), (1984, 30000), (1985, 33870), (1986, 39690), (1987, 43200), (1988, 58500), (1989, 45600), (1990, 46800), (1991, 54000), (1992, 56700), (1993, 70200), (1994, 78810), (1995, 90000), (1996, 75000), (1997, 97170), (1998, 101430), (1999, 109800), (2000, 108000), (2001, 113400), (2002, 115800), (2003, 90900), (2004, 98700), (2005, 103500), (2006, 86400), (2007, 92100), (2008, 91800), (2009, 92700), (2010, 93000)

Livestock_index[Buffalo,Livestock_material_N_concen] = GRAPH(TIME)

(1980, 12.6), (1981, 12.6), (1982, 12.6), (1983, 12.6), (1984, 12.6), (1985, 12.6), (1986, 12.6), (1987, 12.6), (1988, 12.6), (1989, 12.6), (1990, 12.6), (1991, 12.6), (1992, 12.6), (1993, 12.6), (1994, 12.6), (1995, 12.6), (1996, 12.6), (1997, 12.6), (1998, 12.6), (1999, 12.6), (2000, 12.6), (2001, 12.6), (2002, 12.6), (2003, 12.6), (2004, 12.6), (2005, 12.6), (2006, 12.6), (2007, 12.6), (2008, 12.6), (2009, 12.6), (2010, 12.6)

Livestock_index[Buffalo,Livestock_N_concen] = GRAPH(TIME)

(1980, 3.18), (1981, 3.18), (1982, 3.18), (1983, 3.18), (1984, 3.18), (1985, 3.18), (1986, 3.18), (1987, 3.18), (1988, 3.18), (1989, 3.18), (1990, 3.18), (1991, 3.18), (1992, 3.18), (1993, 3.18), (1994, 3.18), (1995, 3.18), (1996, 3.18), (1997, 3.18), (1998, 3.18), (1999, 3.18), (2000, 3.18), (2001, 3.18), (2002, 3.18), (2003, 3.18), (2004, 3.18), (2005, 3.18), (2006, 3.18), (2007, 3.18), (2008, 3.18), (2009, 3.18), (2010, 3.18)

Livestock_index[Buffalo,Livestock_numbers] = GRAPH(TIME)

(1980, 18377), (1981, 18520), (1982, 18770), (1983, 19144), (1984, 19149), (1985, 19506), (1986, 19934), (1987, 20823), (1988, 20823), (1989, 21067), (1990, 21395), (1991, 21690), (1992, 22005), (1993, 22200), (1994, 22548), (1995, 22913), (1996, 23584), (1997, 21722), (1998, 22545), (1999, 22665), (2000, 22587), (2001, 22758), (2002, 22684), (2003, 22724), (2004, 22282), (2005, 22361), (2006, 22495), (2007, 22717), (2008, 23268), (2009, 23267), (2010, 23598)

Livestock_index[Buffalo,Livestock_grassland_ratio] = GRAPH(TIME)

(1980, 0.00), (1981, 0.00), (1982, 0.00), (1983, 0.00), (1984, 0.00), (1985, 0.00), (1986, 0.00), (1987, 0.00), (1988, 0.00), (1989, 0.00), (1990, 0.00), (1991, 0.00), (1992, 0.00), (1993, 0.00),

(1994, 0.00), (1995, 0.00), (1996, 0.00), (1997, 0.00), (1998, 0.00), (1999, 0.00), (2000, 0.00), (2001, 0.00), (2002, 0.00), (2003, 0.00), (2004, 0.00), (2005, 0.00), (2006, 0.00), (2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00)

Straw_feed_ratio = GRAPH(TIME)

(1980, 0.27), (1981, 0.26), (1982, 0.26), (1983, 0.27), (1984, 0.26), (1985, 0.26), (1986, 0.26), (1987, 0.25), (1988, 0.26), (1989, 0.25), (1990, 0.25), (1991, 0.25), (1992, 0.25), (1993, 0.24), (1994, 0.24), (1995, 0.24), (1996, 0.24), (1997, 0.24), (1998, 0.22), (1999, 0.21), (2000, 0.23), (2001, 0.23), (2002, 0.23), (2003, 0.24), (2004, 0.22), (2005, 0.22), (2006, 0.22), (2007, 0.22), (2008, 0.22), (2009, 0.23), (2010, 0.24)

Overall balance

CHANS(t) = CHANS(t - dt) + (IN - OUT) * dt

INIT CHANS = 0

INFLOWS:

IN = IN\BNF+IN\Fuel+IN\HBNF+IN\Import

OUTFLOWS:

OUT = OUT\atmospheric_circulation+OUT\Export+OUT\N2+OUT\To_ocean

Acc = IN-OUT

IN\BNF = AQIN\BNF + CLIN\BNF + ARRAYSUM(FRIN\BNF[*]) + GLIN\BNF + UGIN\BNF

IN\Fuel = HMIN\Fuel + IDIN\Fuel

IN\HBNF = IDIN\HBNF

IN\Import = LSIN\import

OUT\atmospheric_circulation = ASOUT\Export

OUT\Export = ARRAYSUM(LSOUT\Meat[*]) + ARRAYSUM(GLOUT\Food[*]) - ARRAYSUM(HMIN\Animal[*]) + ARRAYSUM(AQOUT\Fish[*])- ARRAYSUM(HMIN\Fish[*])

OUT\N2 = AQOUT\N2 + CLOUT\N2 + FROUT\N2 + GLOUT\N2 + SWOUT\N2 + UGOUT\N2 + WTOUT\N2

OUT\To_ocean = SWOUT\Export

Pet subsystem

Pet(t) = Pet(t - dt) + (PTIN - PTOUT) * dt

INIT Pet = 0

INFLOWS:

PTIN = PTIN\Feed

OUTFLOWS:

PTOUT = PTOUT\Landfill+PTOUT\Manure

PTIN\Feed = Population/Household_size*(House_cat_ratio*0.88*3.6*365+House_dog_ratio*0.56*20*365)/10^10

PTOUT\Landfill = PTIN-PTOUT\Manure

PTOUT\Manure =
Population/Household_size*Human_index[Urban,Population_ratio]*(House_cat_ratio*0.88*3.6*365/10^12/2+House_dog_ratio*0.56*20*365/10^12)
Household_size = GRAPH(TIME)
(1980, 4.50), (1981, 4.46), (1982, 4.41), (1983, 4.37), (1984, 4.32), (1985, 4.28), (1986, 4.22), (1987, 4.15), (1988, 4.09), (1989, 4.02), (1990, 3.96), (1991, 3.90), (1992, 3.84), (1993, 3.78), (1994, 3.72), (1995, 3.66), (1996, 3.70), (1997, 3.64), (1998, 3.63), (1999, 3.58), (2000, 3.44), (2001, 3.46), (2002, 3.40), (2003, 3.38), (2004, 3.36), (2005, 3.13), (2006, 3.17), (2007, 3.17), (2008, 3.16), (2009, 3.13), (2010, 3.12)
House_cat_ratio = GRAPH(TIME)
(1980, 2.00), (1981, 2.00), (1982, 2.00), (1983, 2.00), (1984, 2.00), (1985, 2.00), (1986, 2.20), (1987, 2.40), (1988, 2.60), (1989, 2.80), (1990, 3.00), (1991, 3.20), (1992, 3.40), (1993, 3.60), (1994, 3.80), (1995, 4.00), (1996, 4.20), (1997, 4.40), (1998, 4.60), (1999, 5.00), (2000, 5.40), (2001, 5.80), (2002, 6.20), (2003, 6.60), (2004, 7.00), (2005, 7.40), (2006, 7.80), (2007, 8.20), (2008, 8.60), (2009, 9.00), (2010, 9.40)
House_dog_ratio = GRAPH(TIME)
(1980, 10.2), (1981, 10.4), (1982, 10.6), (1983, 10.8), (1984, 11.0), (1985, 11.2), (1986, 11.4), (1987, 11.6), (1988, 11.8), (1989, 12.0), (1990, 12.2), (1991, 12.4), (1992, 12.6), (1993, 12.8), (1994, 13.0), (1995, 13.2), (1996, 13.4), (1997, 13.6), (1998, 13.8), (1999, 14.0), (2000, 14.2), (2001, 14.4), (2002, 14.6), (2003, 14.8), (2004, 15.0), (2005, 15.2), (2006, 15.4), (2007, 15.6), (2008, 15.8), (2009, 16.0), (2010, 16.2)

Surface water subsystem

Surface_water(t) = Surface_water(t - dt) + (SWIN - SWOUT) * dt
INIT Surface_water = 0
INFLOWS:
SWIN = SWIN\Runoff+SWIN\Deposition
OUTFLOWS:
SWOUT = SWOUT\Export+SWOUT\Irrigation+SWOUT\N2+SWOUT\N2O
SWIN\Deposition = Deposition_rate*9.6*1.82/10^3
SWIN\Runoff = AQOUT\Runoff + CLOUT\Runoff + FROUT\Runoff + ARRAYSUM(HMOUT\Discharged[*]) + IDOUT\Wastewater + ARRAYSUM(LSOUT\Runoff[*]) + UGOUT\Runoff + WTOUT\Runoff
SWOUT\Export = SWIN - SWOUT\Irrigation - SWOUT\N2 - SWOUT\N2O
SWOUT\Irrigation = CLIN\Irrigation
SWOUT\N2 = SWIN*0.5
SWOUT\N2O = SWIN*0.01

Urban greenland subsystem

Urban__greenland(t) = Urban__greenland(t - dt) + (UGIN - UGOUT) * dt
INIT Urban__greenland = 0
INFLOWS:

UGIN = UGIN\BNF+UGIN\Deposition+UGIN\Fertilizer+UGIN\Manure
OUTFLOWS:
UGOUT = UGOUT\Burning+UGOUT\Landfill+UGOUT\Leaching+UGOUT\N2+UGOUT\N2O +UGOUT\NH3+UGOUT\Runoff
UGIN\BNF = UG_Area*18/10^9
UGIN\Deposition = Deposition_rate*UG_Area/10^9
UGIN\Fertilizer = UG_Area*300*0.3/10^9
UGIN\Manure = PTOUT\Manure
UGOUT\Burning = UGOUT\Landfill
UGOUT\Landfill = UG_Area*(0.3*3*0.88*0.03+0.7*7*0.5*0.002)/2/10^6
UGOUT\Leaching = UGIN*0.05
UGOUT\N2 = UGIN*0.2
UGOUT\N2O = UGIN*0.0125
UGOUT\NH3 = UGIN*0.13
UGOUT\Runoff = UGIN*0.07
UG_Area = GRAPH(TIME)
(1980, 286762), (1981, 291758), (1982, 298090), (1983, 322483), (1984, 324864), (1985, 346893), (1986, 424548), (1987, 456507), (1988, 474549), (1989, 458421), (1990, 482899), (1991, 490265), (1992, 504049), (1993, 540945), (1994, 585645), (1995, 647312), (1996, 665119), (1997, 682238), (1998, 745654), (1999, 778161), (2000, 865295), (2001, 946634), (2002, 1.1e+006), (2003, 1.2e+006), (2004, 1.3e+006), (2005, 1.5e+006), (2006, 1.5e+006), (2007, 1.7e+006), (2008, 1.7e+006), (2009, 2e+006), (2010, 2.1e+006)

Wastewater treatment subsystem

Wastewater(t) = Wastewater(t - dt) + (WTIN - WTOUT) * dt
INIT Wastewater = 0
INFLOWS:
WTIN = WTIN\Domestic+WTIN\Waste_Leakage
OUTFLOWS:
WTOUT = WTOUT\Leaching+WTOUT\N2+WTOUT\N2O+WTOUT\Runoff
WTIN\Domestic = ARRAYSUM(HMOUT\Treated[*])
WTIN\Waste_Leakage = GTOUT\Leakage
WTOUT\Leaching = WTIN*0.09
WTOUT\N2 = WTIN*0.3
WTOUT\N2O = WTIN*0.0125
WTOUT\Runoff = WTIN - WTOUT\Leaching - WTOUT\N2 - WTOUT\N2O

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