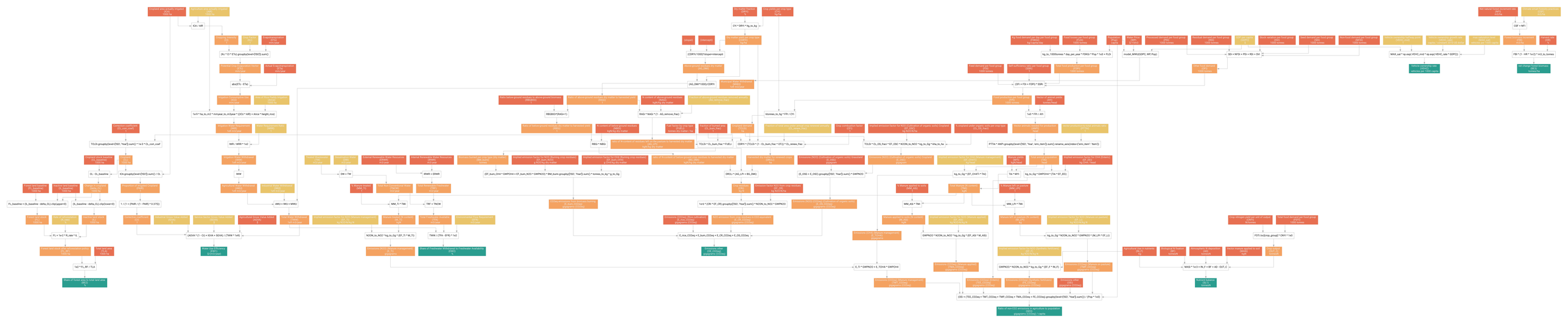

Cropland demand
(TCLDi)
ha

TCLDi.groupby(level=['ISO', 'Year']).sum() * 1e-3 * CL_corr_coef TCLDi * CL_burn_frac * FUELi CDRYi * (TCLDi * (1 - CL_burn_frac * CFi)) * CL_renew_frac TCLDi * CL_OS_fraci * EF_OSC * N2ON_to_NO2 * kg_to_Gg * kha_to_ha

ktonnes_to_hg * FPi / CYi

Crop yields per crop type
(CYi)
hg/ha

CYi * DRYi * hg_to_kg

Food production per food group
(FPi)
1000 tonnes

1e3 * FPi / AYi

(OFi + FDi + FDPi) * SSRi

Food losses per food group
(FLOi)
1000 tonnes

kg_to_1000tonnes * day_per_year * FDKGi * Pop * 1e3 + FLOi

Kg food demand per day per food group
(FDKGi)
kg/capita/day

Self-sufficiency ratio per food group
(SSRi)
1

Total food production per food group
(FDPi)
1000 tonnes

Other food demand

(OFi)
1000 tonnes

SDi + NFDi + PDi + RDi + SVi

Seed demand per food group
(SDi)
1000 tonnes

Non-food demand per food group
(NFDi)
1000 tonnes

Processed demand per food group
(PDi)
1000 tonnes

Residual demand per food group
(RDi)
1000 tonnes

Stock variation per food group
(SVi)
1000 tonnes

Feed demand per food group
(FDi)
1000 tonnes

Population
(Pop)
capita

(OEi + (TEE_CO2eq + TMT_CO2eq + TMP_CO2eq + TMA_CO2eq + FE_CO2eq).groupby(level=['ISO', 'Year']).sum()) / (Pop * 1e3)

model_MWU(GDPC, WP, Pop)

Cropland
(CL)
1000 ha

CL - CL_baseline ICA.groupby(level=['ISO']).sum() / CL

Cropland stock baseline
(CL_baseline)
1000 ha

Change in cropland
(delta_CL)
1000 ha

FL_baseline + (IL_baseline - delta_CL).clip(upper=0) (IL_baseline - delta_CL).clip(lower=0)

Inactive land baseline

(IL_baseline)
1000 ha

Forest land baseline

(FL_baseline)
1000 ha

Inactive land stock

(IL)
1000 ha

FL + 1e-2 * R_rate * IL

Forest land stock

(FL)
1000 ha

Total land area

(TLA)
1000 ha

1e2 * FL_RF / TLA

Rate of reforestation

(R_rate)
%

Forest land stock after reforestation policy
(FL_RF)
1000 ha

Share of forest area to total land area

(BE2)
%

Correction coefficient

(CL_corr_coef)
1

Net natural forest increment rate

(NFI)
m3/ha

CSF + NFI

Climate smart forestry practices
(CSF)
m3/ha

Forest biomass increment

(FBI)
m3/ha

FBI * (1 - HR * 1e-2) * m3_to_tonnes

Harvest rate

(HR)
%

net change forest biomass
(BE3)
tonnes/ha

Total food demand per food group
(FDTi)
1000 tonnes

FDTi.loc[crop_group] * CNYi * 1e3

Crop nitrogen yield per unit of output
(CNYi)
N/tonnes

Crop output
(OUT_C)
tonnesN

MASi * 1e-3 + IN_F + BF + AD - OUT_C

Biological N fixation
(BF)
tonnesN

Atmospheric N deposition
(AD)
tonnesN

Agricultural Use in nutrients
(IN_F)
kg

GWPN2O * N2ON_to_NO2 * kg_to_Gg * (EF_F * IN_F)

Vector manure applied to soil
(MASi)
kgN

Nutrient balance

(SL1)
tonnesN

Total animal population
(TAi)
head

kg_to_Gg * (EF_CH4Ti * TAi) TAi * MYi kg_to_Gg * GWPCH4 * (TAi * EF_EEi)

PTTAi * ANPi.groupby(level=['ISO', 'Year', 'emi_item']).sum().rename_axis(index={"emi_item": 'Item'})

Manure yields
(MYi)
kgN/head

Total Manure (N content)
(TMi)
kgN

MM_Ti * TMi MM_ASi * TMi MM_LPi * TMi

Vector of animal yields
(AYi)
tonnes/head

Vector animals needed for production
(ANPi)
head

vector production-to-total animals ratio
(PTTAi)
1

% Manure applied to soils
(MM_ASi)
1

% Manure left on pasture
(MM_LPi)
1

% Manure treated

(MM_Ti)
1

Manure treated (N content)
(M_Ti)
kgN

N2ON_to_NO2 * kg_to_Gg * (EF_Ti * M_Ti)

Manure left on pasture (N content)
(M_LPi)
kg

kg_to_Gg * N2ON_to_NO2 * GWPN2O * (M_LPi * EF_Li)

Manure applied to soils (N content)
(M_ASi)
kgN

GWPN2O * N2ON_to_NO2 * kg_to_Gg * (EF_ASi * M_ASi)

Implied emission factor for N2O (Manure on pasture)
(EF_Li)
kg N2O-N/kg N

Emissions (CO2eq) (Manure on pasture)
(TMP_CO2eq)
gigagrams (CO2eq)

Implied emission factor for N2O (Manure management)
(EF_Ti)
kg N2O-N/kg N

Implied emission factor for CH4 (Manure management)
(EF_CH4Ti)
kg/head

Emissions (N2O) (Manure management)
(E_Ti)
gigagrams

E_Ti * GWPN2O + E_TCH4i * GWPCH4

Emissions (CH4) (Manure management)
(E_TCH4i)
gigagrams

Emissions (CO2eq) (Manure management)
(TMT_CO2eq)
gigagrams (CO2eq)

Implied emission factor for N2O (Manure applied)
(EF_ASi)
kg N2O-N/kg N

Emissions (CO2eq) (Manure applied)
(TMA_CO2eq)
gigagrams (CO2eq)

Implied emission factor for CH4 (Enteric)
(EF_EEi)
kg CH4 / head

Emissions (CO2eq) (Enteric)
(TEE_CO2eq)
gigagrams (CO2eq)

Implied emission factor for N2O (Synthetic fertilizers)
(EF_F)
kg N2O-N/kg N

Emissions (CO2eq) (Synthetic fertilizers)
(FE_CO2eq)
gigagrams (CO2eq)

Emissions other

(OEi)
gigagrams (CO2eq)

Ratio of non-CO2 emissions in agriculture to population
(GE3)
gigagrams (CO2eq) / capita

CO2eq emissions from biomass burning
(E_burn_CO2eq)
gigagrams (CO2eq)

E_rice_CO2eq + E_burn_CO2eq + E_CR_CO2eq + E_OS_CO2eq

(EF_burn_CH4 * GWPCH4 + EF_burn_N2O * GWPN2O) * BM_burni.groupby(['ISO', 'Year']).sum() * tonnes_to_kg * g_to_Gg

Emissions (CO2eq) (Rice cultivation)
(E_rice_CO2eq)
gigagrams (CO2eq)

N2O emission from crop residues in CO2-equivalent
(E_CR_CO2eq)
gigagrams (CO2eq)

1e-6 * (CRi * EF_CR).groupby(['ISO', 'Year']).sum() * N2ON_to_NO2 * GWPN2O

Emissions (N2O) (CO2eq) (Cultivation of organic soils)
(E_OS_CO2eq)
gigagrams (CO2eq)

(E_OSG + E_OSC).groupby(['ISO', 'Year']).sum() * GWPN2O

Emissions other

(OE_CO2eq)
gigagrams (CO2eq)

fraction of burned area

(CL_burn_frac)
1

Fuel factor by crop type
(FUELi)
tonnes dry matter / ha

Biomass burned per crop type (dry matter)
(BM_burni)
tonnes

Implied emission factor for N2O (Burning crop residues)
(EF_burn_N2O)
g N20/kg dry matter

Implied emission factor for CH4 (Burning crop residues)
(EF_burn_CH4)
g CH4/kg dry matter

% cropland under organic soils per crop type
(CL_OS_fraci)
1

Emissions (N2O) (Cultivation of organic soils) Grassland
(E_OSG)
gigagram

Implied emission factor for N2O (Cultivation of organic soils) Cropland
(EF_OSC)
kg N2O-N/ha

Emissions (N2O) (Cultivation of organic soils) Cropland
(E_OSC)
gigagram

Dry matter fraction
(DRYi)
%

Dry matter yield per crop type
(CDRYi)
kg/ha

(CDRYi/1000)*slopei+intercepti

(AG_DMi*1000)/CDRYi

(slopei) (intercepti)

Above-ground residues dry matter
(AG_DMi)

Ratio of above-ground residues dry matter to harvested yield
(RAGi)
1

RBGBIOi*(RAGi+1) RAGi * NAGi * (1 - AG_remove_frac)

Ratio below-ground residues to above-ground biomass
(RBGBIOi)
1

Ratio of below-ground residues dry matter to harvested yield
(RBGi)
1

RBGi * NBGi

Fraction of total area under annual crop renewed annually
(CL_renew_frac)
1

Fraction of above-ground residues removed annually
(AG_remove_frac)
1

N content of above-ground residues
(NAGi)
kgN/kg dry matter

N content of below-ground residues
(NBGi)
kgN/kg dry matter

Crop combustion factor
(CFi)
1

Harvested dry matter for renewed crops
(DRCLi)
ha

DRCLi * (AG_LPi + BG_DMi)

ratio of N-content of residues left on the pasture to harvested dry matter
(AG_LPi)
kgN/kg dry matter

ratio of N-content of below-ground crop residues to harvested dry matter
(BG_DMi)
kgN/kg dry matter

Crop residues
(CRi)
kg N

Emission factor N2O from crop residues
(EF_CR)
kg N2O-N/ha

Crop Factor
(Kc)
1

(Kc * CI * ETo).groupby(level=['ISO']).sum()

Cropland area actually irrigated
(ICA)
1000 ha

ICA / AIR

Cropping Intensity
(CI)
1

Evapotranspiration
(ETo)
mm/year

Potential Crop Evaporation Vector
(ETc)
mm/year

abs(ETc - ETa)

Actual Evapotranspiration
(ETa)
mm/year

Irrigation Consumptive Use
(ICU)
mm/year

1e-9 * ha_to_m2 * mmyear_to_m3year * ((ICU * AIR) + Arice * height_rice)

Agriculture area actually irrigated
(AIR)
1000 ha

Area of Rice Paddy Irrigation
(Arice)
1000 ha

Water Requirement Ratio
(WRR)
1

IWR / WRR * 1e2

Irrigation Water Requirement
(IWR)
1e9 m3/year

Irrigation Water Withdrawal
(IWW)
1e9 m3/year

IWW

Agricultural Water Withdrawal
(AWU)
1e9 m3/year

AWU + IWU + MWU

Water Price

(WP)
$/15m3

GDP per capita
(GDPC)
$

MAX_sat * np.exp(-VEHC_mid * np.exp(-VEHC_rate * GDPC))

Municipal Water Withdrawal
(MWU)
1e9 m3/year

Industrial Water Withdrawal

(IWU)
1e9 m3/year

Total Water Withdrawal

(TWW)
1e9 m3/year

(AGVA * (1 - Cr) + IGVA + SGVA) / (TWW * 1e9) TWW / (TFA - EFR) * 1e2

Agricultural Gross Value Added
(AGVA)
$

Proportion of Irrigated Cropland
(PAIR)
1

1 / (1 + (PAIR / (1 - PAIR) * 0.375))

Corrective coefficient

(Cr)
1

Industrial Gross Value Added

(IGVA)
$

Service Sector Gross Value Added

(SGVA)
$

Water Use Efficiency
(EW1)
$/(m3/year)

Internal Renewable Water Resources

(IRWR)
m3/year

IRWR + ERWR

External Renewable Water Resources

(ERWR)
m3/year

Total Renewable Freshwater

(TRF)
m3/year

TRF + TNCW

Desalination Water

(DW)
m3/year

DW + TW

Treated Wastewater

(TW)
m3/year

Total Non Conventional Water

(TNCW)
m3/year

Total Freshwater Available

(TFA)
m3/year

Environmental Flow Requirement
(EFR)
m3/year

Share of Freshwater Withdrawal to Freshwater Availability
(EW2)
%

Vehicle ownership rate
(VEHC)
vehicles per 1000 capita

max saturation level

(MAX_sat)
vehicles per 1000 capita

Vehicle ownership halfway point
(VEHC_mid)
1

Vehicle ownership growth rate
(VEHC_rate)
capita / constant 2010 US dollar