**Table S1** Equations of the direct processes calculating $NH_3$ volatilization from upland soils in the original and modified CNMM-DNDC model.

| Equations | Description | |
|---|---|---|
| ***Original CNMM-DNDC model*** | | |
| **Urea hydrolysis** | | |
| $d[NH_4^+]_j/dt = -d[\text{urea}]_j/dt$ $= f_T f_{SOC}\,[\text{urea}]_j$ | Urea hydrolysis rate | Eq. 1 |
| $f_T = 0.0364e^{0.0805T_{soil}}$ | Effect of soil temperature on urea hydrolysis | Eq. 2 |
| $f_{SOC} = 0.01[SOC]_j^{-1}$ | Effect of soil temperature on urea hydrolysis | Eq. 3 |
| **ABC decomposition** | | |
| $f_{ABC\_dec} = f_{pH} f_{dp}$ | ABC decomposition rate | Eq. 4 |
| $f_{pH} = 0.1\text{pH} - 0.5$ | Effect of soil pH on ABC decomposition | Eq. 5 |
| $f_{dp} = 6.0 \times 10^{-3.6735j/q - 0.7551}$ | Effect of soil depth on ABC decomposition | Eq. 6 |
| $NH_{3\_flux(j)} = f_{ABC\_dec}[NH_4HCO_3]_j$ | $NH_3$ volatilization from ABC decomposition | Eq. 7 |
| **$NH_3$ volatilization** | | |
| $\text{Flux}(NH_3)_{upland(j)} = 0.25 f_{wind} f_{depth} f_{temp} [NH_{3(l)}]_j$ | $NH_3$ flux from uplands | Eq. 8 |
| $f_{wind} = 1.5S_{wind}/(1.0 + S_{wind})$ | Effect of wind speed on $NH_3$ volatilization | Eq. 9 |
| $f_{depth} = (\frac{d_s}{d_l} - j)/\left(\frac{d_s}{d_l}\right)$ | Effect of soil depth on $NH_3$ volatilization | Eq. 10 |
| $f_{temp} = T_{soil}/(50 + T_{soil})$ | Effect of soil temperature on $NH_3$ volatilization | Eq. 11 |
| ***Modified CNMM-DNDC model*** | | |
| **Urea hydrolysis** | | |
| $d[NH_4^+]_j/dt = -d[\text{urea}]_j/dt$ $= f_T f_{SOC} f_{SM} [\text{urea}]_j$ | Urea hydrolysis rate | Eq. 12 |
| $f_T = 0.45e^{0.025T_{soil}}$ | Effect of soil temperature on urea hydrolysis | Eq. 13 |

| | | |
|---|---|---|
| $f_{SM}$ = WFPS/PORE | Effect of soil moisture on urea hydrolysis | Eq. 14 |
| $f_{SOC}$= $0.01[SOC]_j^{-1}$ | Effect of soil temperature on urea hydrolysis | Eq. 15 |
| **ABC decomposition** | | |
| $f_{ABC\_dec} = f_{pH} f_{dp} f_{T_s\_ABC}$ | ABC decomposition rate | Eq. 16 |
| $f_{pH}$= $0.1pH - 0.5$ | Effect of soil pH on ABC decomposition | Eq. 17 |
| $f_{dp} = 6.0 \times 10^{-3.6735j/q-0.7551}$ | Effect of soil depth on ABC decomposition | Eq. 18 |
| $f_{T_s\_ABC} = T_{soil}/(30 + T_{soil})$ | Effect of soil temperature on ABC decomposition | Eq. 19 |
| $NH_{3\_flux(j)} = f_{ABC\_dec}[NH_4HCO_3]_j$ | $NH_3$ volatilization from ABC decomposition | Eq. 20 |
| **$NH_3$ volatilization** | | |
| $Flux(NH_3)_{upland(j)}$ $= 3.6 f_{wind} f_{depth} f_{temp} f_{canopy} f_{clay} f_{water} f_{rain} [NH_{3(l)}]_j$ | $NH_3$ flux from uplands | Eq. 21 |
| $f_{wind} = 0.1 + 1.5S_{wind}/(1 + S_{wind})$ | Effect of wind speed on $NH_3$ volatilization | Eq. 22 |
| $f_{depth} = 0.5^{d_{soil}/0.03}$ | Effect of soil depth on $NH_3$ volatilization | Eq. 23 |
| $f_{temp} = 0.1 + 2.0T_{soil}/(45 + T_{soil})$ | Effect of soil temperature on $NH_3$ volatilization | Eq. 24 |
| $f_{canopy} = 0.4e^{-0.15lai} + 0.6$ | Effect of dry canopy on $NH_3$ volatilization | Eq. 25 |
| $f_{clay} = e^{-0.06cl}$ | Effect of soil clay content on $NH_3$ volatilization | Eq. 26 |
| $f_{water} = 0.45e^{-10WFPS_j/PORE} + 0.55$ | Effect of soil moisture on $NH_3$ volatilization | Eq. 27 |
| $f_{rain} = 0.65e^{-1.0laiP} + 0.35$ | Effect of rain wetting canopy on $NH_3$ volatilization | Eq. 28 |