Abstract & more results!

EGU23-10546, BG3.18 | Carbon stocks in cool temperate forests with different stand structure due to deer overgrazing

Hayato ABE (abe.hayato.360@s.Kyushu-u.ac.jp)・ Tomonori KUME・ Ayumi KATAYAMA (Kyushu University, Japan)

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Reference： [1] Myers Madeira, 2008. *Resources for the Future.* [2] Shawn et al. 2020, Trends Ecol. Evol. [3] Saruki et al., 2014, Bull. Kyushu Univ. For. [4] Enoki et al., 2017, Bull. Kyushu Univ. For. [5] Shinoda and Akasaka, 2020, Sci. Rep.

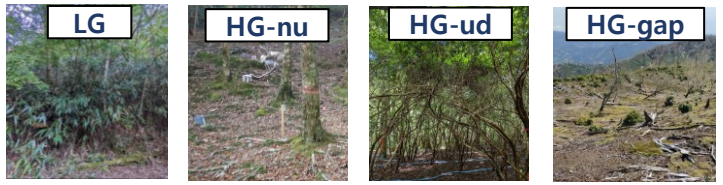
1. Introduction

- **Target:** Maintain forest carbon (C) stocks [1].
- **Focus:** Vegetation foraging by over-populated mammals (**overgrazing**) in Northern hemisphere [2].
- **Issue**: Unclear impacts of overgrazing on forest C stocks through changes in forests structure.

Aim: Quantify the effects of sika deer overgrazing on above- and below-ground C stocks by altering forest structure in Kyushu islands, Japan.

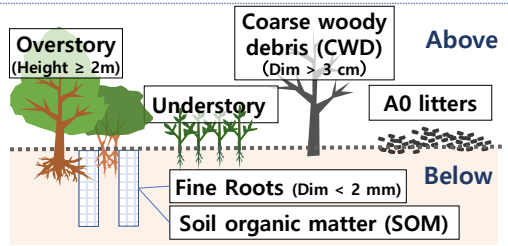
2. Methods

- **Sites: Mixed forests of conifer and broadleaf tree under deer overgrazing pressure since the 1980's** [3].
- **Stands: Four plots (100~400 m²) were installed in:**
  1. **Less grazed (LG);** Forest with understory vegetation [3],
  2. **Heavily grazed (HG) -no understory (HG-nu);** Forest with loss of understory vegetation [3],
  3. **HG-unpalatable shrubs dominant (HG-ud);** Forest dominated by unpalatable shrubs, *Pieris japonica* [4],
  4. **HG-canopy gaps (HG-gap);** Forest with canopy gap areas where inhibition of regeneration [5].



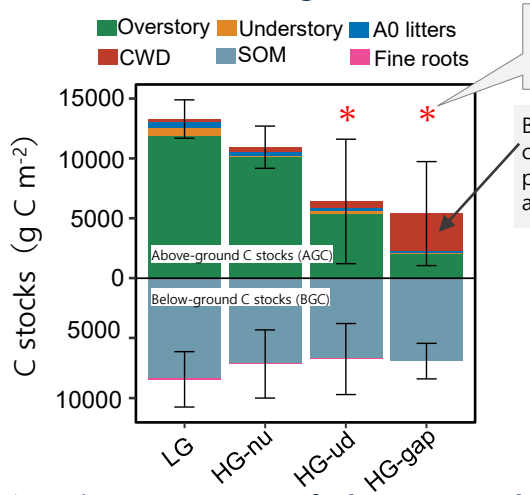
- **C stocks:**

Estimated by components (≒ Dry mass × C content



3. Results and Discussions

- **Above- and Below-ground C stocks**

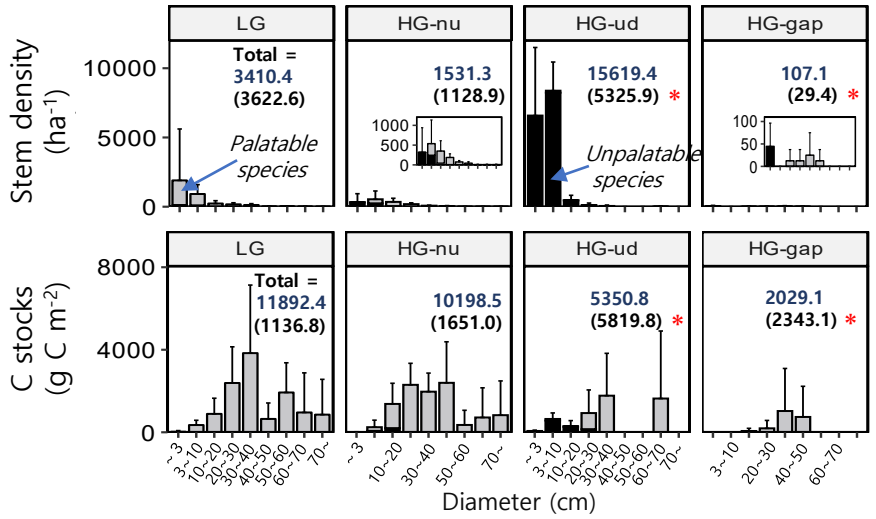


* $p < 0.05$ difference from LG (two-sided Dunnet test)

Bars indicates mean values of each components obtained from replicate plots; error bars indicates SD of above- and below-ground C stocks.

✓ **Heavily grazed (HG) stands had up to 50~60% lower above-ground C stocks compared with LG, mainly due to lower C stocks of overstory trees.**

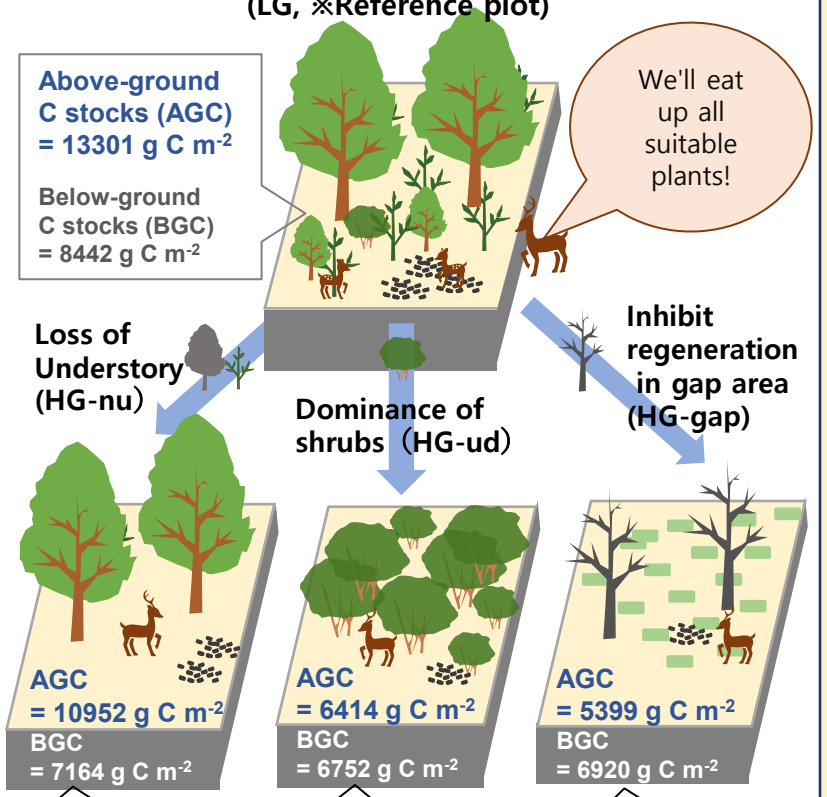
- **Main components of Above-ground C stocks: Overstory trees**



✓ **Deer grazing reduces palatable small-diameter trees, thereby reduces large-diameter trees, and eventually reduces overstory C.**

Highlights | Deer overgrazing since 1980, has reduced above-ground carbon stocks up to 60%, primarily through the inhibit regeneration of palatable trees.

Less grazed mixed forests with understory vegetation (LG, ※Reference plot)



Palatable small trees and herbaceous plants were lost (*but C stock has not yet been affected).

Shrubs were densely distributed but smaller in height and trunk size, resulting in a 50% lower AGC.

Lack of overstory trees resulted in a 60% lower AGC. Many amount of CWD mitigate such C loss.

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Supplementally materials | S1. Introduction

Background

- Maintaining forest carbon (C) stocks is one of the goal of the forest management [1].
- Northern hemisphere forests are being affected by vegetation foraging by overpopulated mammals (overgrazing) [2].

→ It is necessary to monitor whether overgrazing decreases C stock.

Previous studies and Research gaps

- Many previous studies have tested the impact of overgrazing on forest C by comparing a portion of the forest C components inside and outside of mammal exclusion fences [e.g., Tanentzap et al., 2012, Biol. Rev.] .
- However, there were limited studies focusing on:
  - Both above-and below-ground forest C stocks,
  - Variety of overgrazing-induced vegetation conditions occurring outside the fence.

Study aim

- To quantify the impact of Japanese sika deer overgrazing on above- and below-ground C stock by comparing multiple stand types with altered forest structure in Kyushu island, Japan, due to over 20-years grazing of Japanese sika deer.

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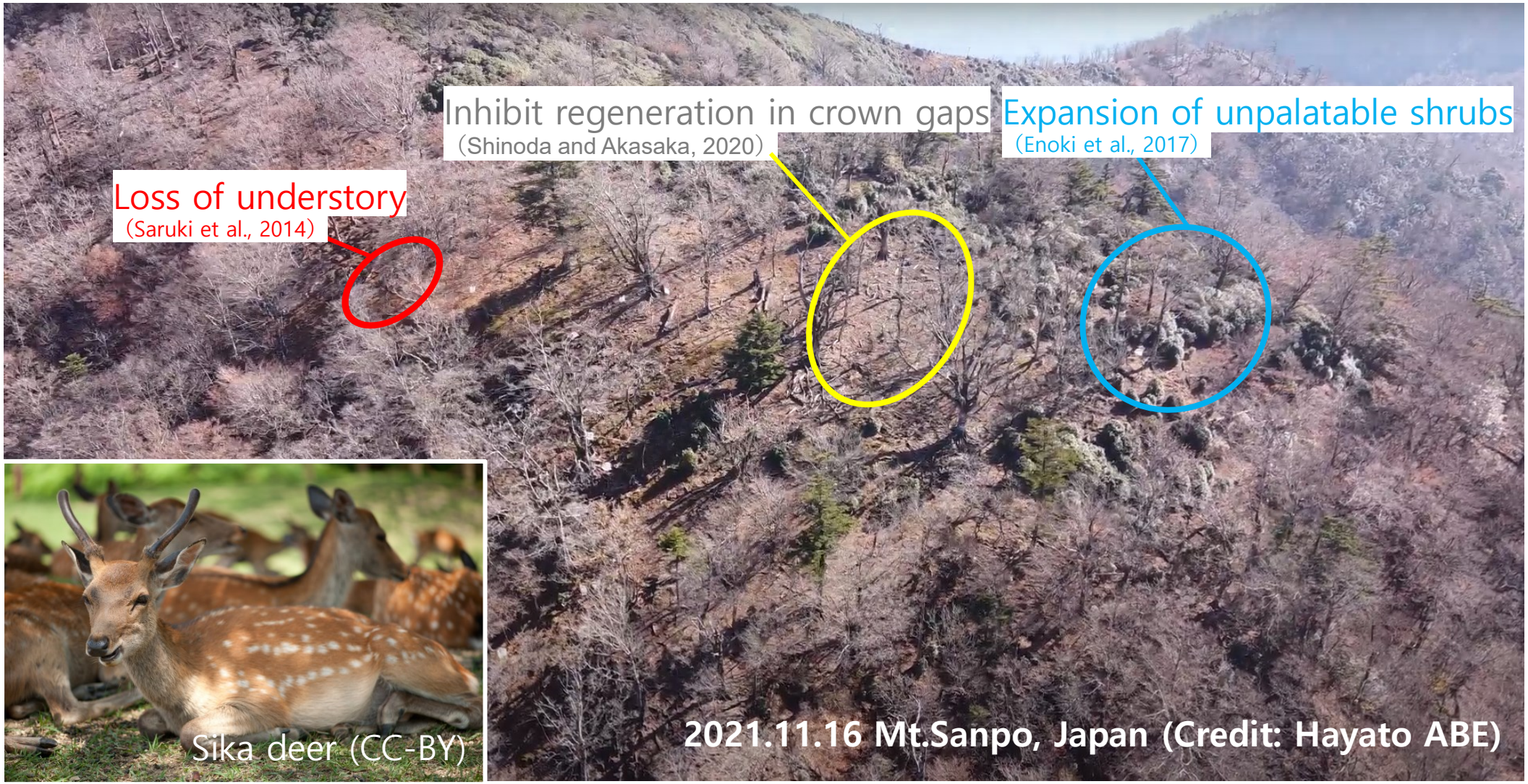
S2. Evidence photographs of variety of overgrazing-induced vegetation conditions



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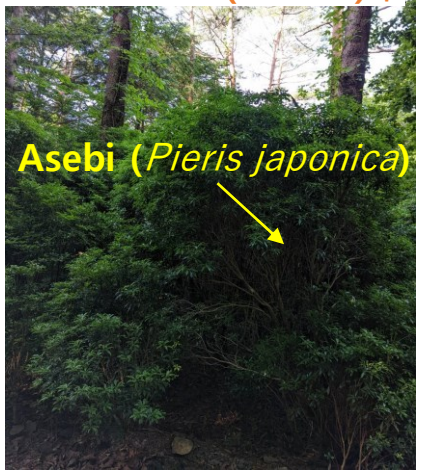
S3. Photographs of the targeted stand types

Less grazed forest (LG)

Heavily grazed forest with crown gap (HG-gap)

Heavily grazed forest with loss of understory (HG-nu).

Heavily grazed forest with dominance of unpalatable shrubs (HG-ud) ↓



HG-ud：
The dominant species is deer unpalatable shrubs, Asebi tree (Ericaceae family, *Pieris japonica*), with a few species of pine, oak, and fir mixed in. The community height is 3-4 m, reflecting the height of the Asebi trees.

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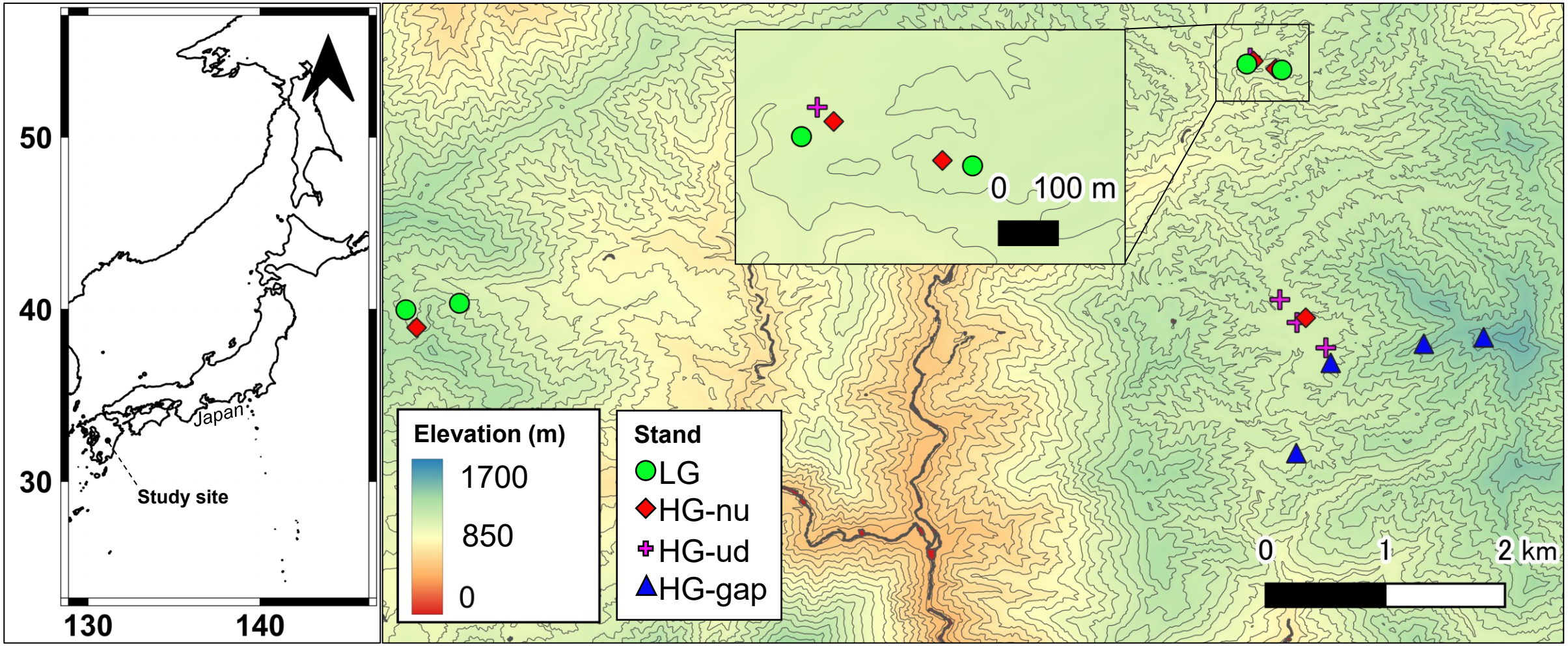
S4. Location of study site and plots



Location of the study area (left) and plot (right). Contour intervals are 50 m. LG: Less grazed mixed forest, HG-nu: Heavily grazed mixed forest without no understory, HG-ud: Heavily grazed forest dominated by unpalatable shrubs, HG-gap: Heavily grazed forest with regeneration inhibited crown gap area.

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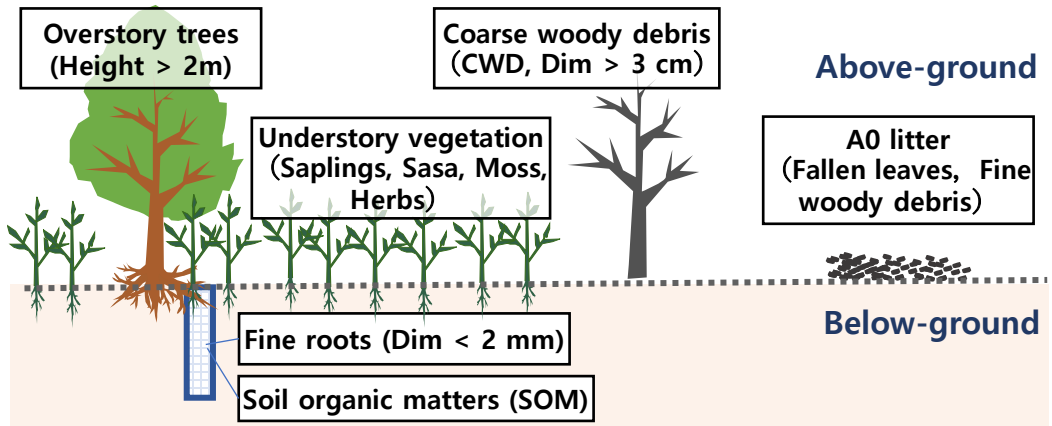
S5. Detail of measurements

Forest C stocks were evaluated by 6 components.

C stocks (g C m^{-2})
≒ Dry mass (g m^{-2})
× C content (g C g^{-1})

Sampling date
Overstory and understory：July to August 2022
Other components：October to November 2022



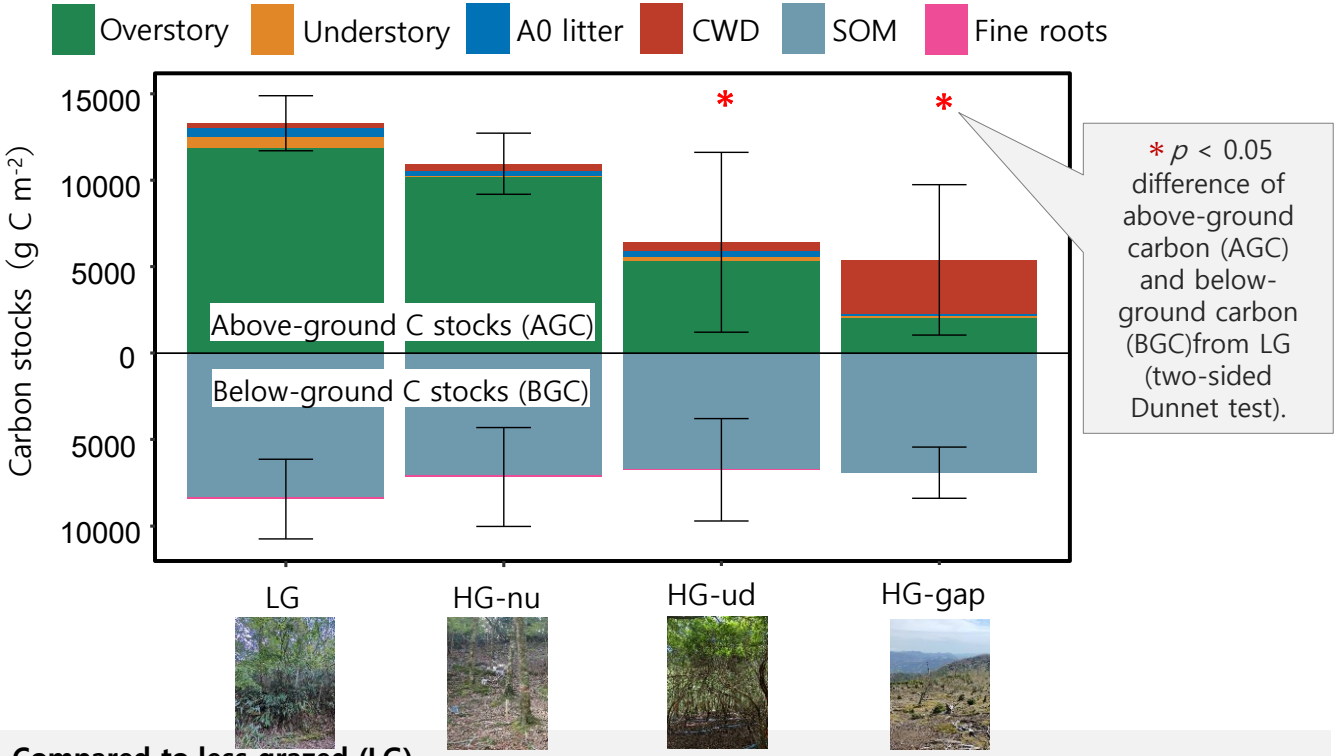
Measurement of dry mass

① **Overstory**：Recorded diameter at breast height and species per plot → Estimated biomass by allometric equation [6].
② **Understory**：Sampling at 0.25 m^2 × 8 points per plot.
③ **A0 litter**： Sampling at 0.04 m^2 × 4 points per plot.
④ **CWD**：Sampling per plot:
Small CWD (Dim 3~10 cm)→ Collected by decay level.
Large CWD (> 10 cm)→Measured volume (m^3) by decay level.
→Dry mass = Volume × Wood density by decay level [7].
⑤ **Fine roots and ⑥ SOM**：
Sampling at 0.02 m^2 × 30 cm depth × 5 points per plot.

Reference： [6] Ishihara et al. 2015, Ecol. Appl. [7] Prescott and Grayston 2023. For. Ecol. Manag.

S6. Differences in carbon stocks

Heavily grazed (HG) stands have lower AGC compared with less grazed (LG).



Compared to less grazed (LG)....

- **Loss of understory vegetation (HG-nu):** No difference in above-ground carbon stocks (AGC) and below-ground carbon stocks (BGC).
- **Dominance of unpalatable shrubs (HG-ud):** 50% lower AGC and no difference in BGC.
- **Inhibition of regeneration in gap area (HG-gap):** 60% lower AGC and no difference in BGC.
- **Factors reducing AGC:** Reduction of C stocks from overstory trees, understory vegetation, and A0 litter (mainly overstory trees).
- **Stability of BGC:** Although a decrease could not be confirmed, BGC in HG-ud and HG-gap may be decreased in the future, reflecting the low amount of above-ground production.

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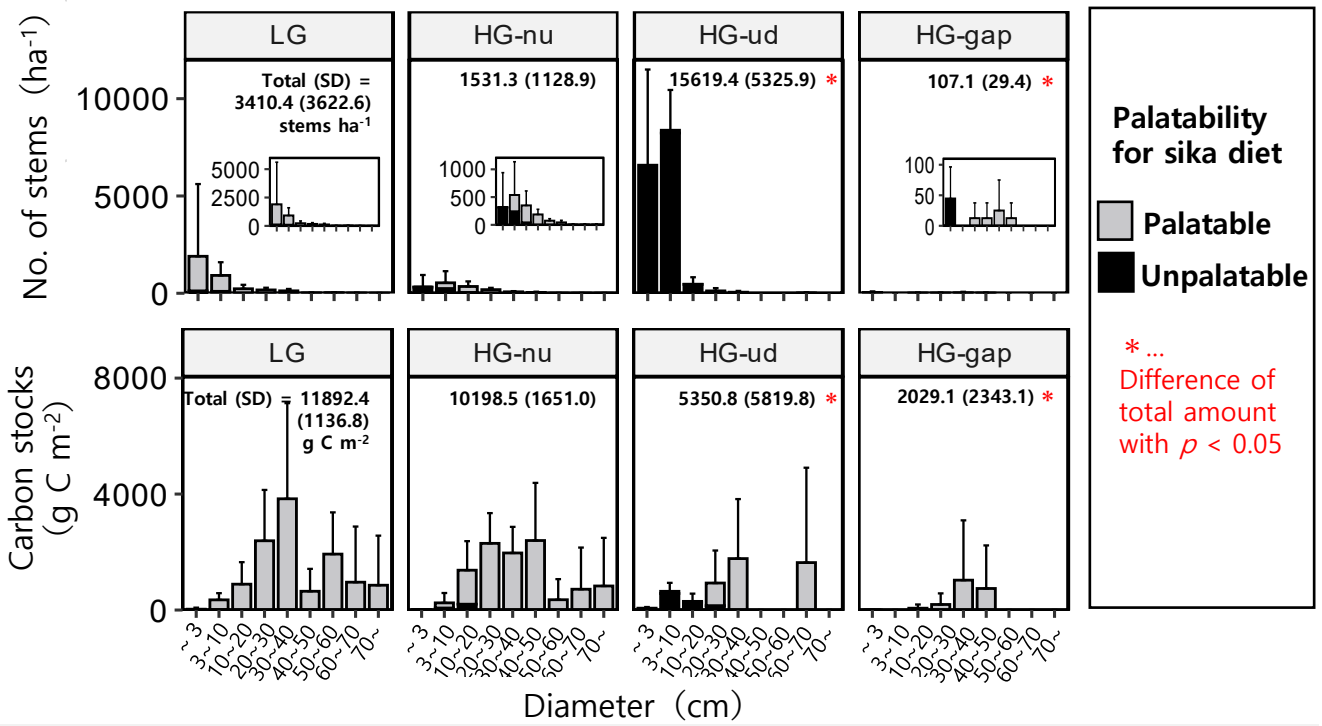
S7. AGC: Overstory trees

Deer grazing reduces palatable small-diameter trees, thereby reduces large-diameter trees, and eventually reduces overstory C stocks.

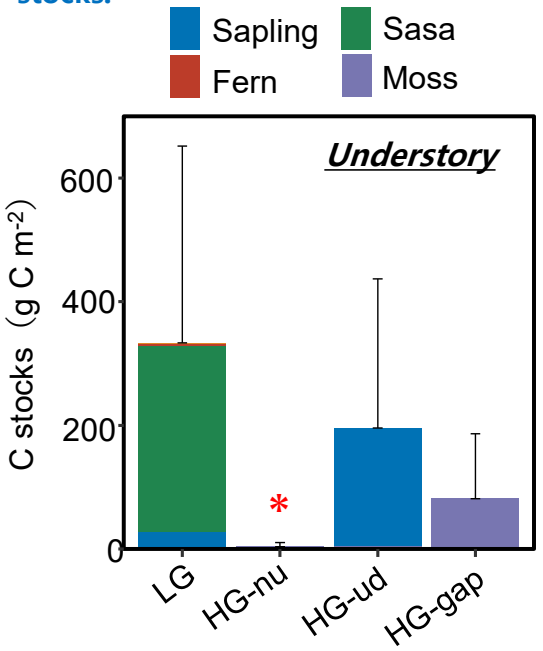


- **HG-nu**：Fewer palatable small diameter (<10 cm diameter) trees than that of CP. Because of low biomass of individual in small trees, total C stocks was not differed to CP.
  →Overstory C stocks will decrease due to lack of successional trees.
- **HG-ud**：Higher stem density of unpalatable shrubs (Asebi) than that in CP. Because of low biomass of Asebi, total C stocks were 50% lower than that in CP.
- **HG-gap**：Due to lack of overstory trees, stem density was 90% lower, and C stocks was 80% lower than that in LG.

Reference： [8] Schreiner et al. 1996, Can. Jour. For. Res. [9] Mizuno et al., 2020, Sci. Rep.

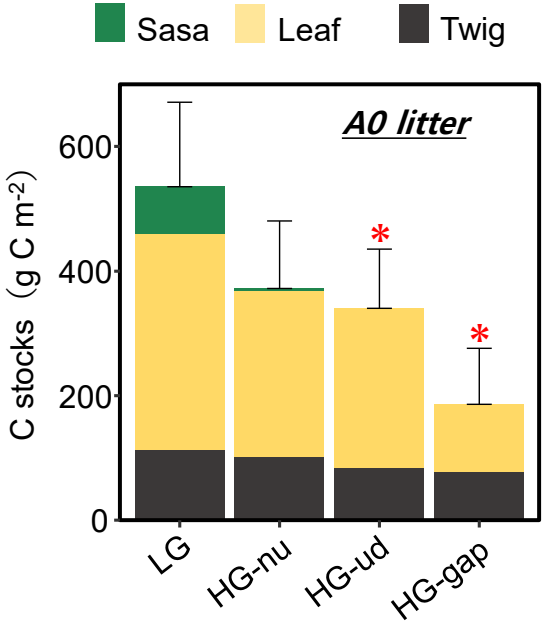
S8. AGC: Understory vegetation and A0 litters

Deer grazing eliminates dominant understory species and reduce C stocks.



- **HG stands:** Loss of Sasa species (dominant understory in LG).
  →**90% lower C stocks in HG-nu.**
- **HG-ud, HG-gap: Replacement of unpalatable understory** such as saplings of Asebi [4] and Moss [8]. These mitigate C reduction induced by loss of Sasa.

Reduction of overstory and understory vegetation promotes the reduction of A0 litter C stocks.



- **HG-nu:** No difference in total amount. Lower sasa & leaf litter than LG ($p < 0.05$).
- **HG-ud, HG-gap:** 40~70% lower total amount than LG. . Lower sasa & leaf litter than LG ($p < 0.05$).
- **Possible reason of lower sasa & leaf litter in HG stands:** Lower production and soil erosion due to loss of understory [9].

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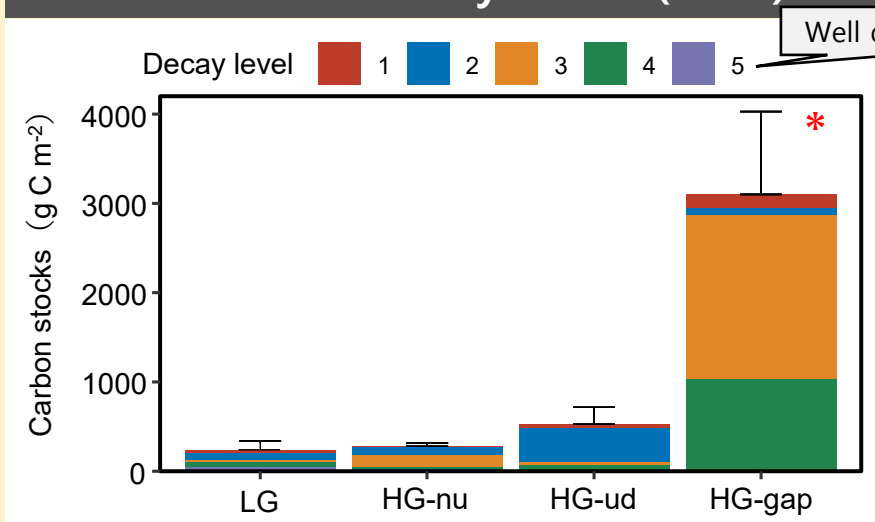
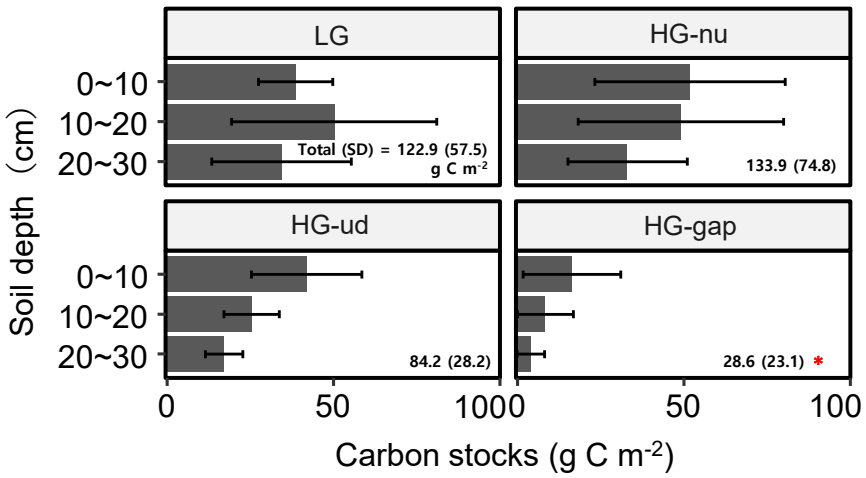
S9. AGC: Coarse woody debris (CWD)



- **HG-gap**：Total amount was 13 – fold higher than that in LG. The majority of CWD in the HG-gap was at decay levels 3 and 4, suggesting that these CWD were generated during the formation of the canopy gap.

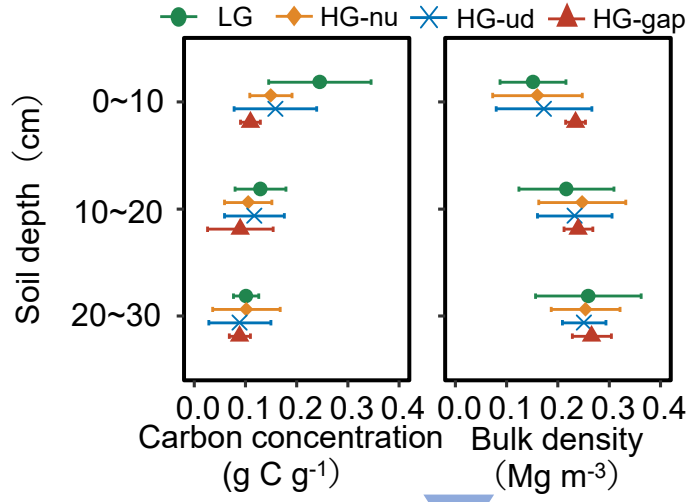
◆ Fine roots



- **HG-nu, HG-ud:** No difference in total amount. →Clarify the reason in further study.
- **HG-gap:** 80% lower total amount than that in LG. → Due to loss of above-ground vegetation.

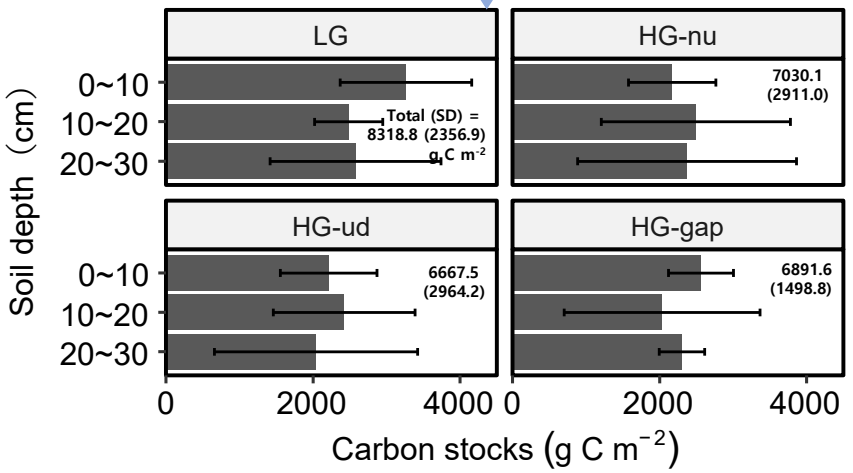
S10. BGC: Fine roots and Soil organic matters (SOM)

◆ Soil organic matter



- **C concentration**: HG stands tends to have lower carbon concentrations than that of LG. → Soil erosion due to loss of understory may reduce it [9].
- **Bulk density**: HG stands tends to have higher bulk density than that of LG. → Soil erosion may remove topsoil with lower bulk density. Trampling by deer may also contribute the increase of bulk density [9].

*C stocks = C concentration * Bulk density*



- **HG stands:** No difference in the total amount compared to LG. →Reduction of C concentration was balanced by the increase of bulk density. → Although we could not confirm a decrease in SOM in this study, BGC will decrease in reflect of the reduction of AGC.

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S11. Summary