Supplementary Data

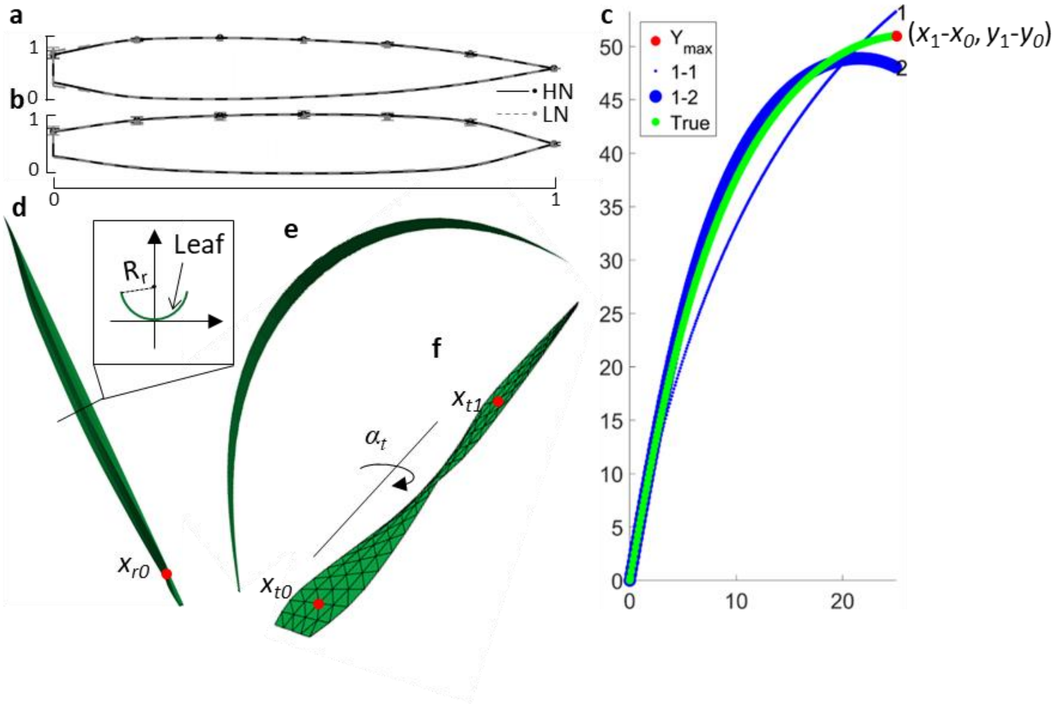

Figure S1. Reconstruction of the 2D and 3D architecture of a rice leaf. A 2D shape of a flag leaf (a) and a 2D shape of a non-flag leaf (b) of high nitrogen treated (HN) and low nitrogen treated (LN) rice cultivar XS134 are illustrated. Note that the leaf shape of two treatments are almost completely overlapped. The 2D curvature of a leaf is solved iteratively c). Finally, 3D leaves with different features can be simulated, e.g., a rolling leaf (d), a curving leaf (e), and a twisting leaf (f).

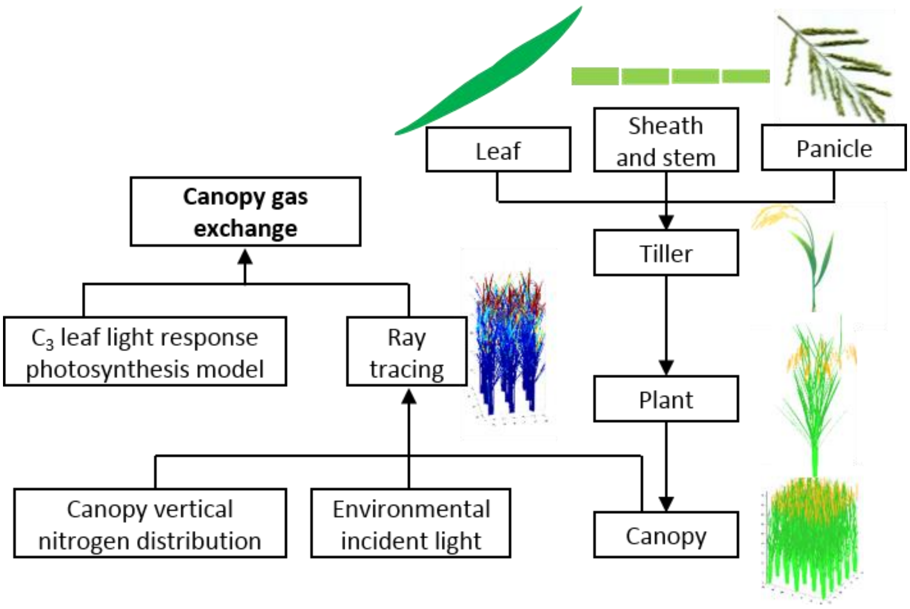

Figure S2. The workflow of 3dCAP reconstruction and canopy photosynthesis calculation. During this process, first the leaf, sheath and stem, and panicle are reconstructed based on the measured architectural parameters. Then a tiller is reconstructed, which is used as the basis to build a single plant. A number of plants together form a canopy. The plant architectures are predicted with these structural components and also a mechanical model of weight distribution. Using information about the incident photosynthetic photon flux density and direction of solar beam and also the distribution of nitrogen in leaves along the canopy vertical layers, a ray tracing algorithm is used to predict the light environments inside a canopy. The light environment is then combined with a C_3 leaf photosynthesis model to predict the canopy photosynthetic CO_2 uptake rate.

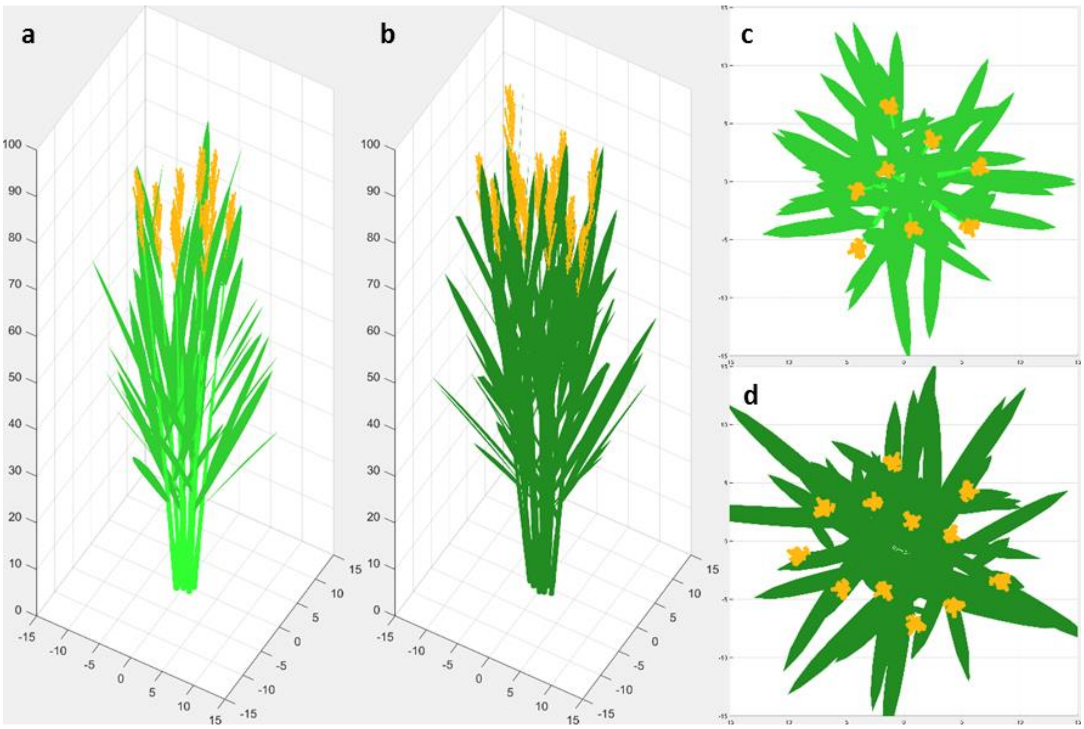

Figure S3. Different views of reconstructed rice plants. The side view (a, b) and birdview (c, d) are shown. The views in a and c represent rice cultivar XS134 under low nitrogen treatment conditions; while views in b and d represent rice cultivar XS134 under high nitrogen treatment. The data used to reconstruct these rice architecture were collected from field experiments conducted in Songjiang breeding station of the Shanghai Institutes of Plant Physiology and Ecology, Shanghai, China in 2015.

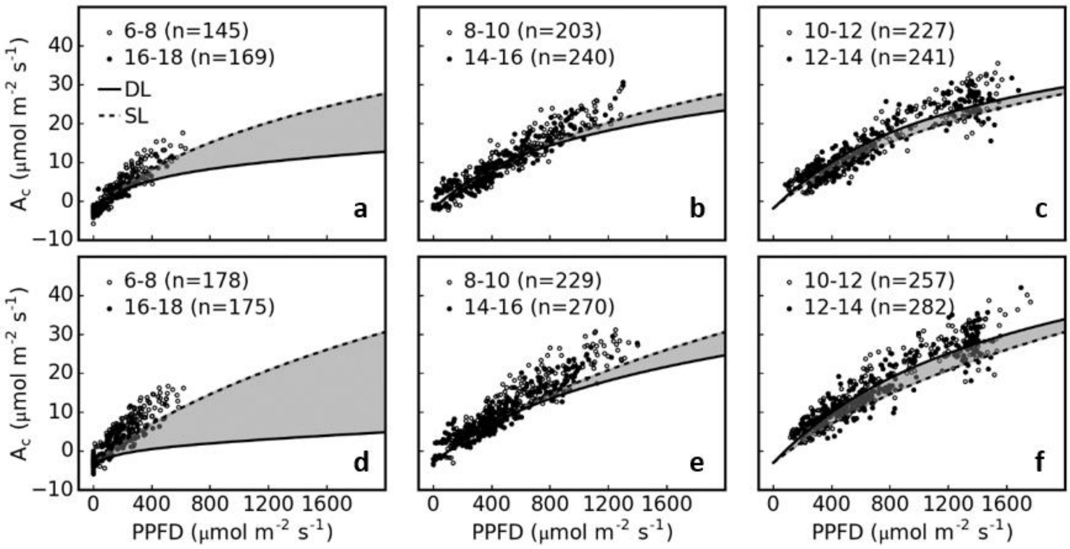

Figure S4. Predicted and measured net canopy photosynthesis rate under different incident light intensity at different times of a day. The net canopy photosynthesis (A_c) of low nitrogen treated (a-c) and high nitrogen treated (d-f) rice cultivar XS134 at 6-to-8 o'clock and 16-to-18 o'clock (a, d), 8-to-10 o'clock and 14-to-16 o'clock (b, e), and 10-to-12 o'clock and 12-to-14 o'clock (c, f) are presented into separate panels. The simulation of A_c on each day was performed by assuming all the incident light to be direct light only (DL) or scattered light only (SL). The measured A_c data was collected from September 11 to September 18 of 2015 in Songjiang breeding station of the Shanghai Institutes of Plant Physiology and Ecology, Shanghai, China.

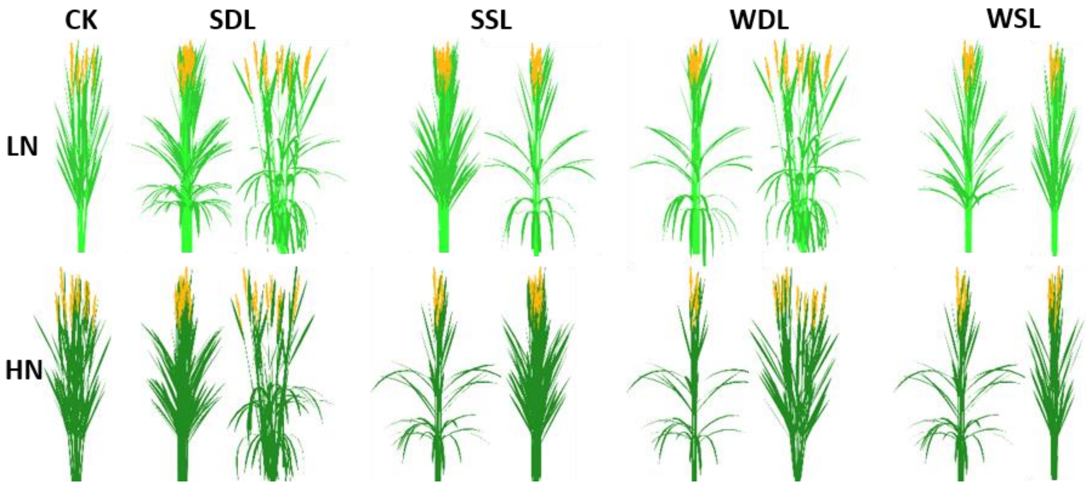

Figure S5. Difference among predicted optimal plant architectures for optimal daily total canopy photosynthetic CO_2 uptake. Plants in the top row represent rice under low nitrogen treatment (LN), plants in the second row represent high nitrogen treatment (HN). The current rice (CK) and predicted optimal plant architectures under four different light environments are illustrated. The four light environments include strong direct light (SDL; Fig. 6a), strong scattered light (SSL; Fig. 6f), weak direct light (WDL; Fig. 6k) and weak scattered light (WSL; Fig. 6p). Two dramatically different plant architectures with similarly high daily total canopy photosynthesis are shown for each group.