

Supplementary Information

Adaptation pathways of global wheat production: Importance of strategic adaptation to climate change

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Supplementary Tables

Supplementary Table S1 | Adaptation levels

| Level | Description |
|---------------------|---|
| Irrigation levels* | |
| 0 | No adaptation (fixed to current irrigated area ratio) |
| 1 to 10 | Increasing irrigated area ratio by X% for crop lands where irrigated ratio in the present > 0 (X=10 for Level 1, 20 for Level 2, ..., 100 for Level 10) |
| 11 | Increasing irrigated area ratio by 100% for crop lands where irrigated ratio in the present > 0, and increasing by 20% for presently non-irrigated crop lands |
| 12 | The same as Level 11 except increasing by 50% for presently non-irrigated crop lands |
| Crop variety levels | |
| 0 | No adaptation (only 4 minor varieties of the present optimal cultivar [†] [defined in the M-GAEZ model] are selectable) |
| 1 | Original 16 varieties defined in the M-GAEZ model are selectable |
| 2 to 4 | A set of 16 new heat-tolerant varieties (assumed by gradually relaxing temperature limitations of high temperatures in the M-GAEZ model) added to the selectable varieties in the previous level are selectable |
| 5 | A set of 16 new heat-tolerant varieties (assumed by removing temperature limitations of high temperatures in the M-GAEZ model) added to the selectable varieties in Level 4 are selectable |

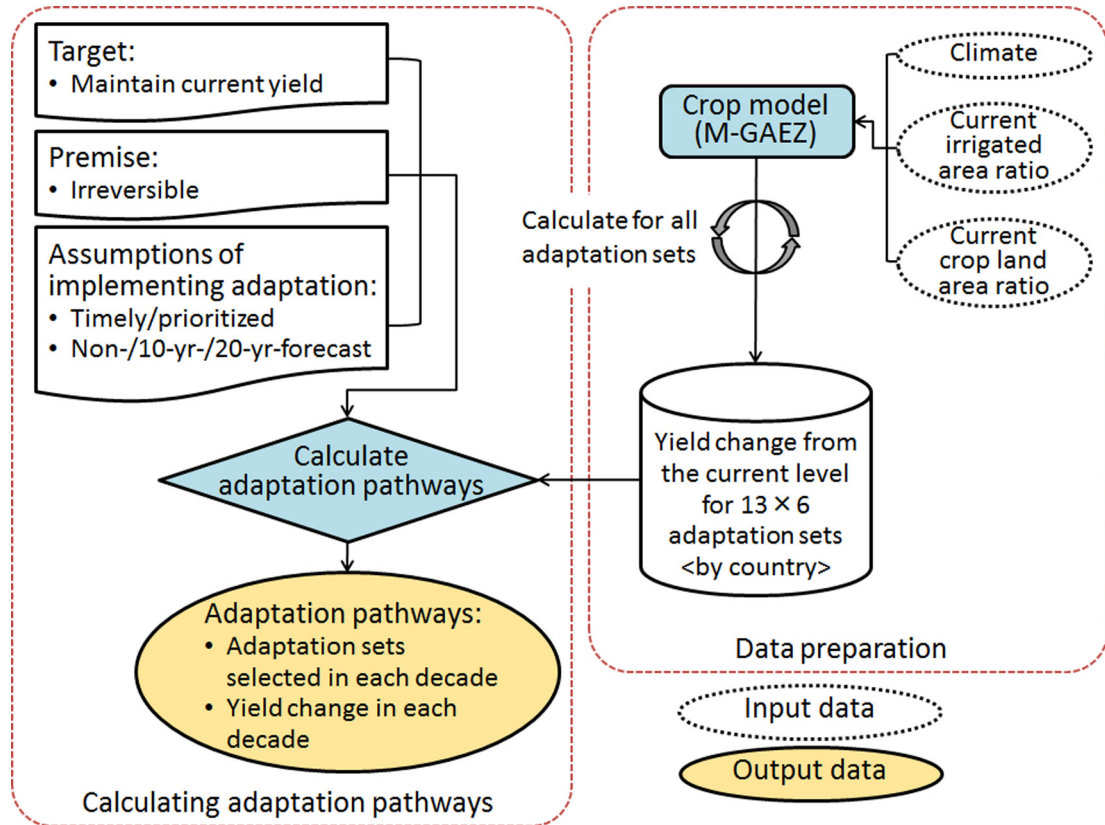
*Upper limit of irrigated area ratio is 100%.

[†]The optimal cultivar is set separately for rain-fed crop lands and irrigated crop lands.

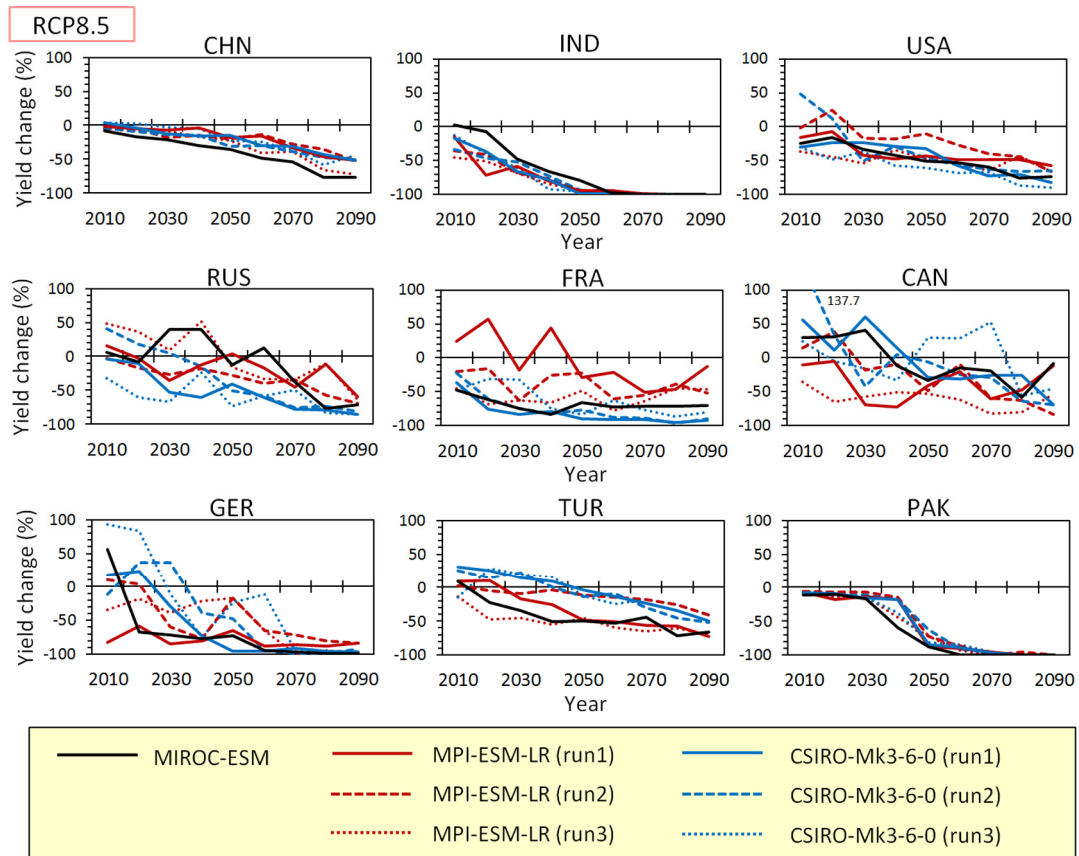
Supplementary Table S2 | Assumptions of implementing adaptation sets to develop adaptation pathways

| Case | Description | Limitation of implementing adaptation | Prioritized adaptation option | Forecast |
|-----------------------|--|---------------------------------------|-------------------------------|-------------|
| Timely | <ul style="list-style-type: none"> • An adaptation set that has the minimum yield change is chosen from among the sets in which yield change is at or above zero • If there are only sets in which yield change is below zero, a set that minimizes the yield decrease is chosen • The adaptation set required in the current decade is implemented immediately in the current decade | none | none | - |
| Prioritized cases | | | | |
| Prioritize irrigation | The same as the timely case, except that the adaptation of irrigation is preferentially chosen | none | irrigation | - |
| Prioritize variety | The same as the timely case, except that the adaptation of crop variety is preferentially chosen | none | crop variety | - |
| Forecast cases | | | | |
| Non-forecast | <p>The same as the timely case, except that:</p> <ul style="list-style-type: none"> • The adaptation set required in the current decade is implemented in the next decade • Adaptation levels actually implemented are limited to one level per decade | one level per decade | none | none |
| 10-yr-forecast | <p>The same as the timely case, except that:</p> <ul style="list-style-type: none"> • The adaptation set to be selected in the next decade is forecast and implemented in the next decade • Adaptation levels actually implemented are limited to one level per decade | one level per decade | none | 10 yr ahead |
| 20-yr-forecast | <p>The same as the timely case, except that:</p> <ul style="list-style-type: none"> • The adaptation set to be selected in the two decades ahead is forecast and implemented in the next decade • Adaptation levels actually implemented are limited to one level per decade | one level per decade | none | 20 yr ahead |

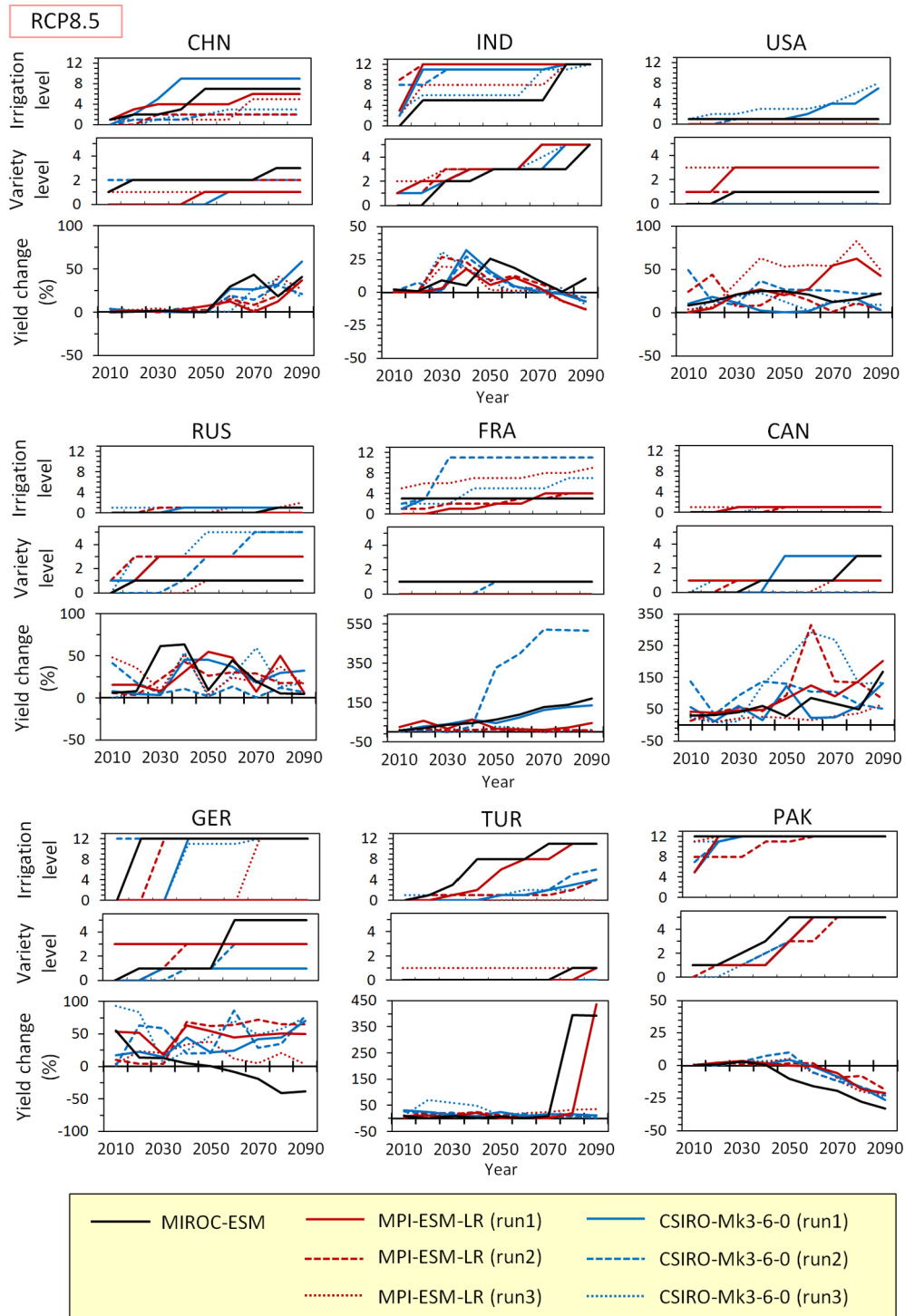
Supplementary Figures



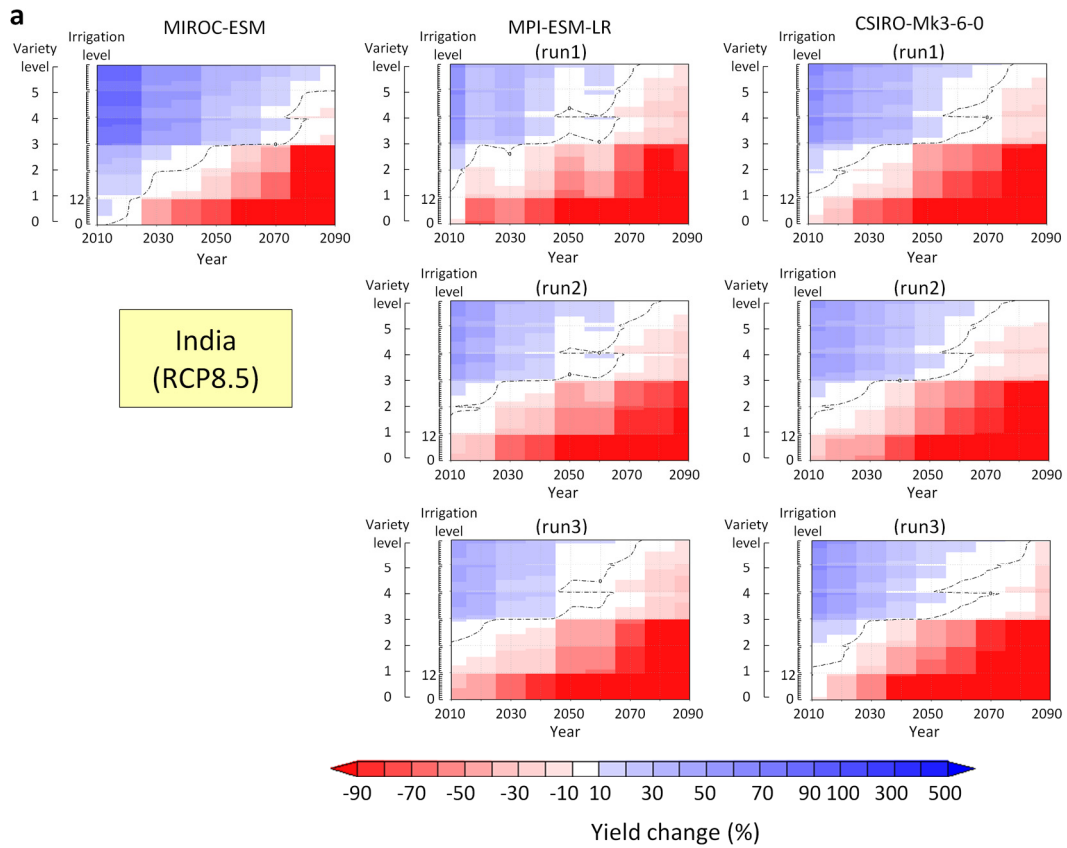
Supplementary Figure S1 | Framework of developing adaptation pathways.



Supplementary Figure S2 | Wheat yield change from the current level without adaptation (i.e., adaptation Level 0 for both irrigation and crop variety) in China (CHN), India (IND), the United States (USA), Russia (RUS), France (FRA), Canada (CAN), Germany (GER), Turkey (TUR), and Pakistan (PAK), under the RCP8.5 scenario. The descriptions “run1”, “run2”, and “run3” correspond to r1i1p1, r2i1p1, and r3i1p1 of the CMIP5 simulations, respectively.

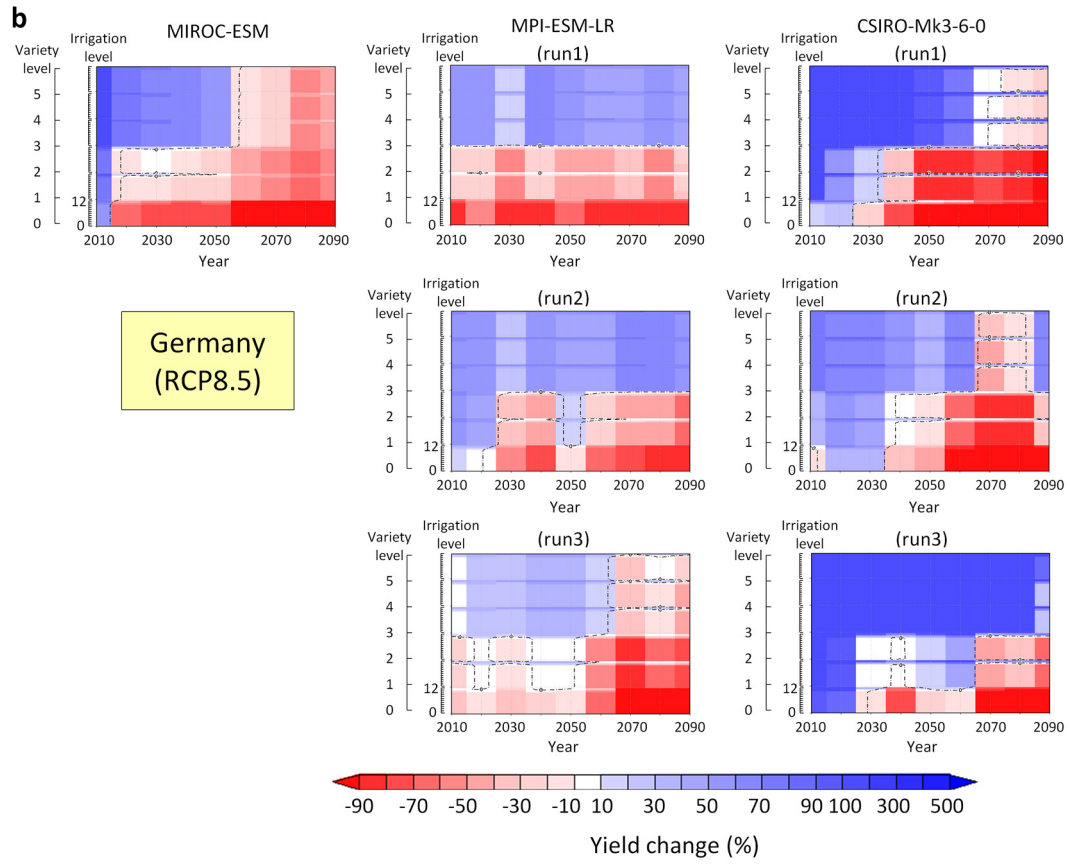


Supplementary Figure S3 | Adaptation pathways and yield change from the current level in the timely case of all the climate projections in China (CHN), India (IND), the United States (USA), Russia (RUS), France (FRA), Canada (CAN), Germany (GER), Turkey (TUR), and Pakistan (PAK), under the RCP8.5 scenario. The descriptions “run1”, “run2”, and “run3” correspond to r1i1p1, r2i1p1, and r3i1p1 of the CMIP5 simulations, respectively.

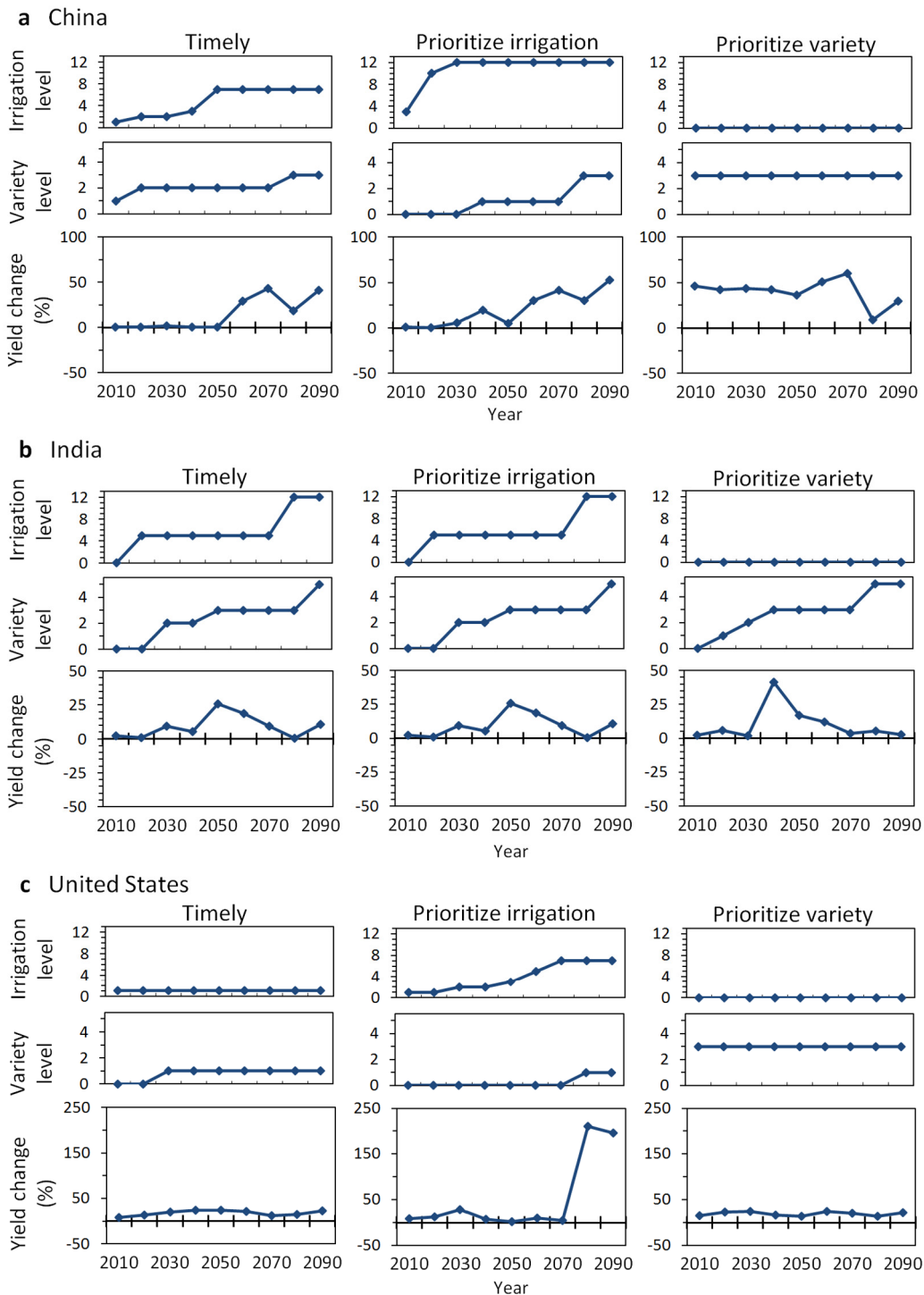


Supplementary Figure S4 | Time evolution of yield change from the current level for all adaptation sets (13 irrigation \times 6 variety) under the RCP8.5 scenario of all the climate projections. The thin black broken lines represent 0% change. The descriptions “run1”, “run2”, and “run3” correspond to r1i1p1, r2i1p1, and r3i1p1 of the CMIP5 simulations, respectively. **a**, India. **b**, Germany.

(Supplementary Figure S4; continued)



RCP8.5

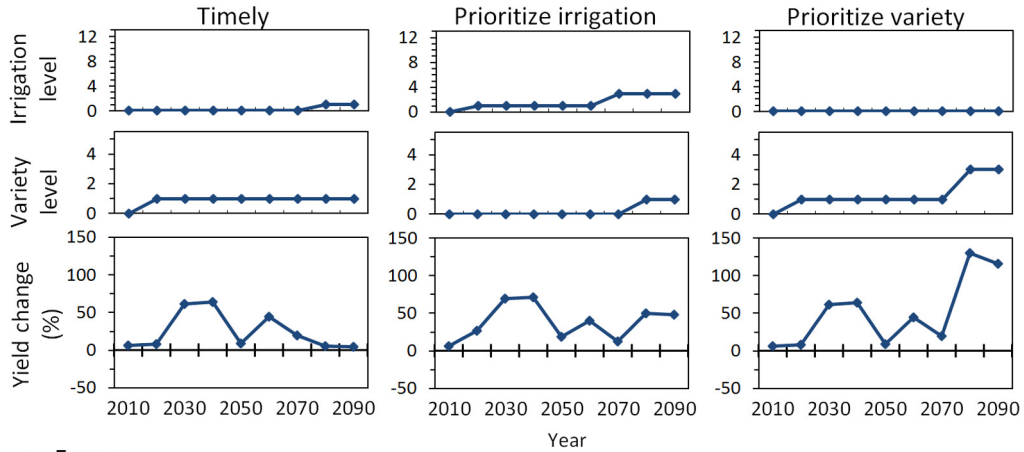


Supplementary Figure S5 | Adaptation pathways and yield change from the current level in the timely case, prioritize irrigation case, and prioritize variety case in the nine countries under the RCP8.5 scenario of the MIROC-ESM projection.

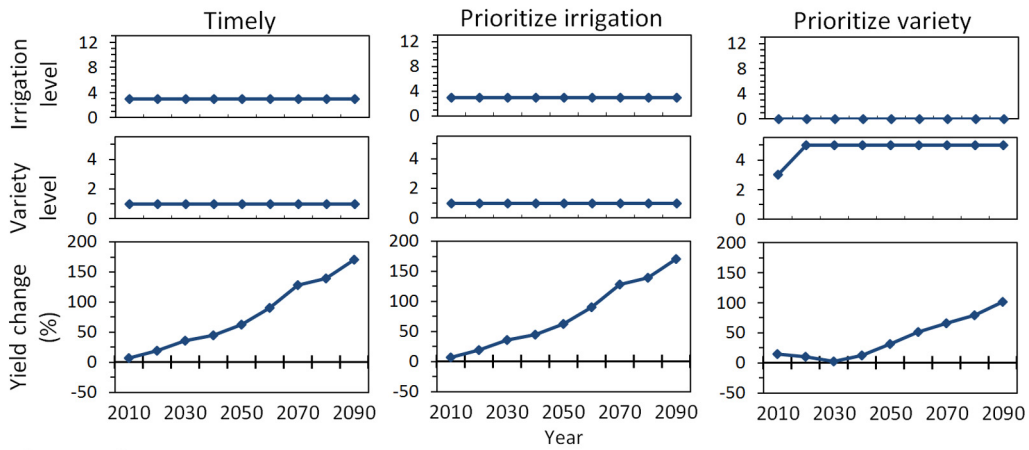
(Supplementary Figure S5; continued)

RCP8.5

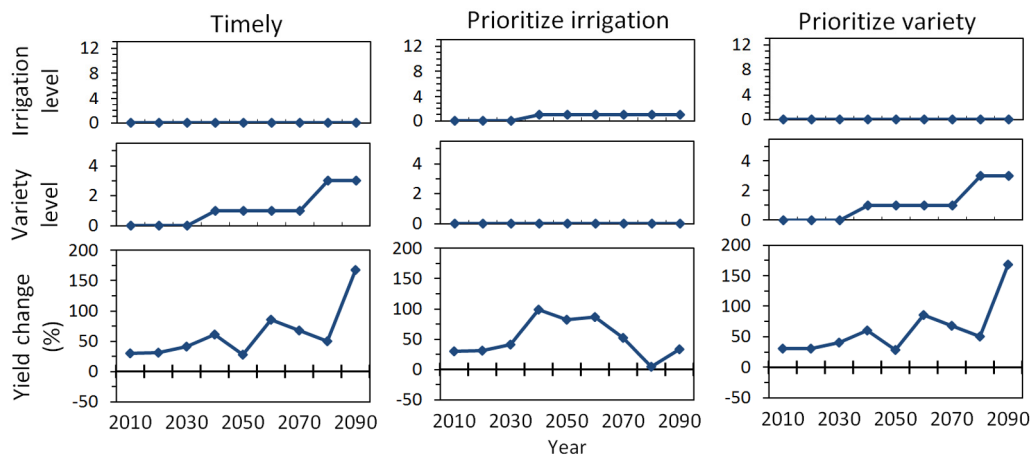
d Russia



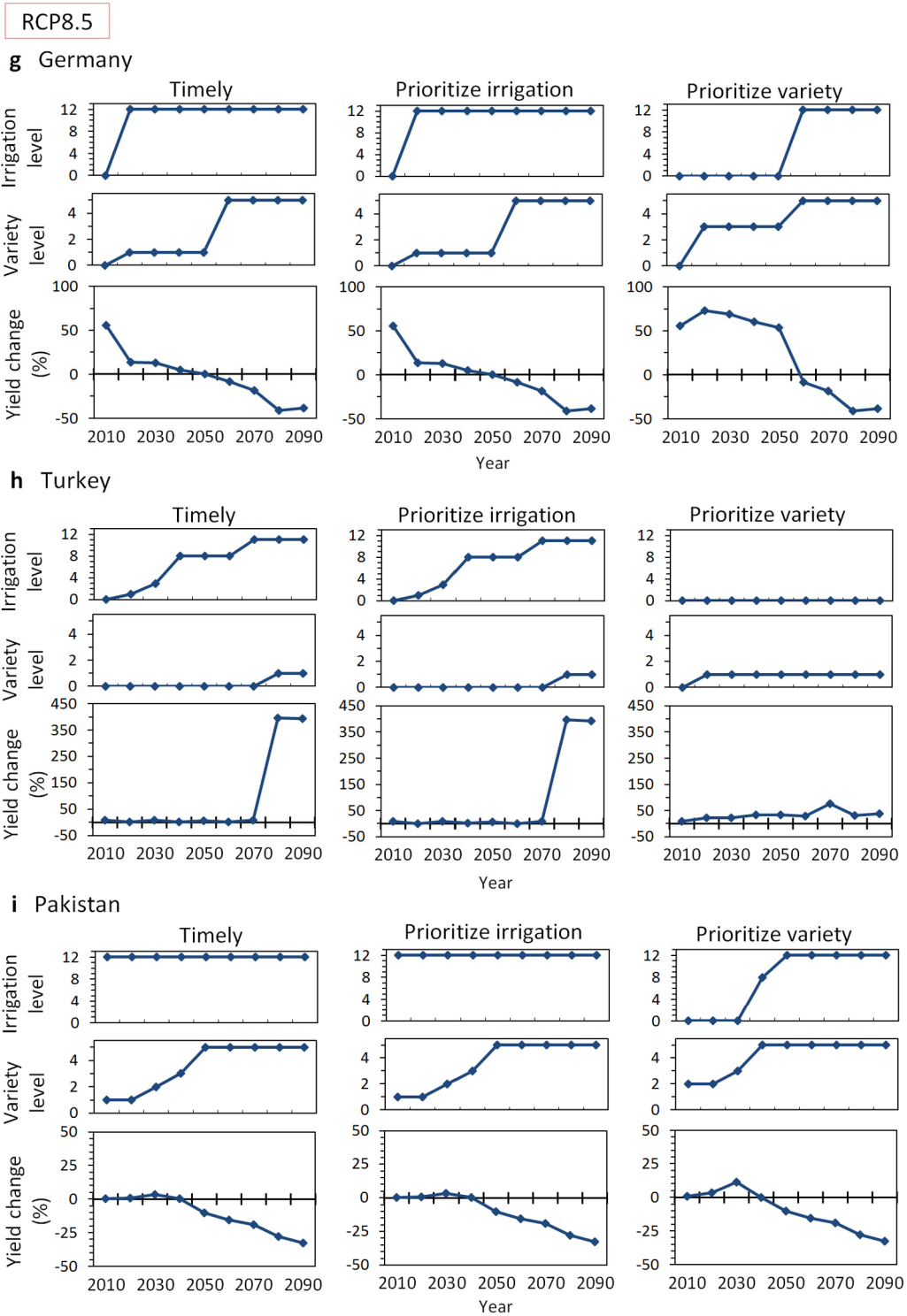
e France



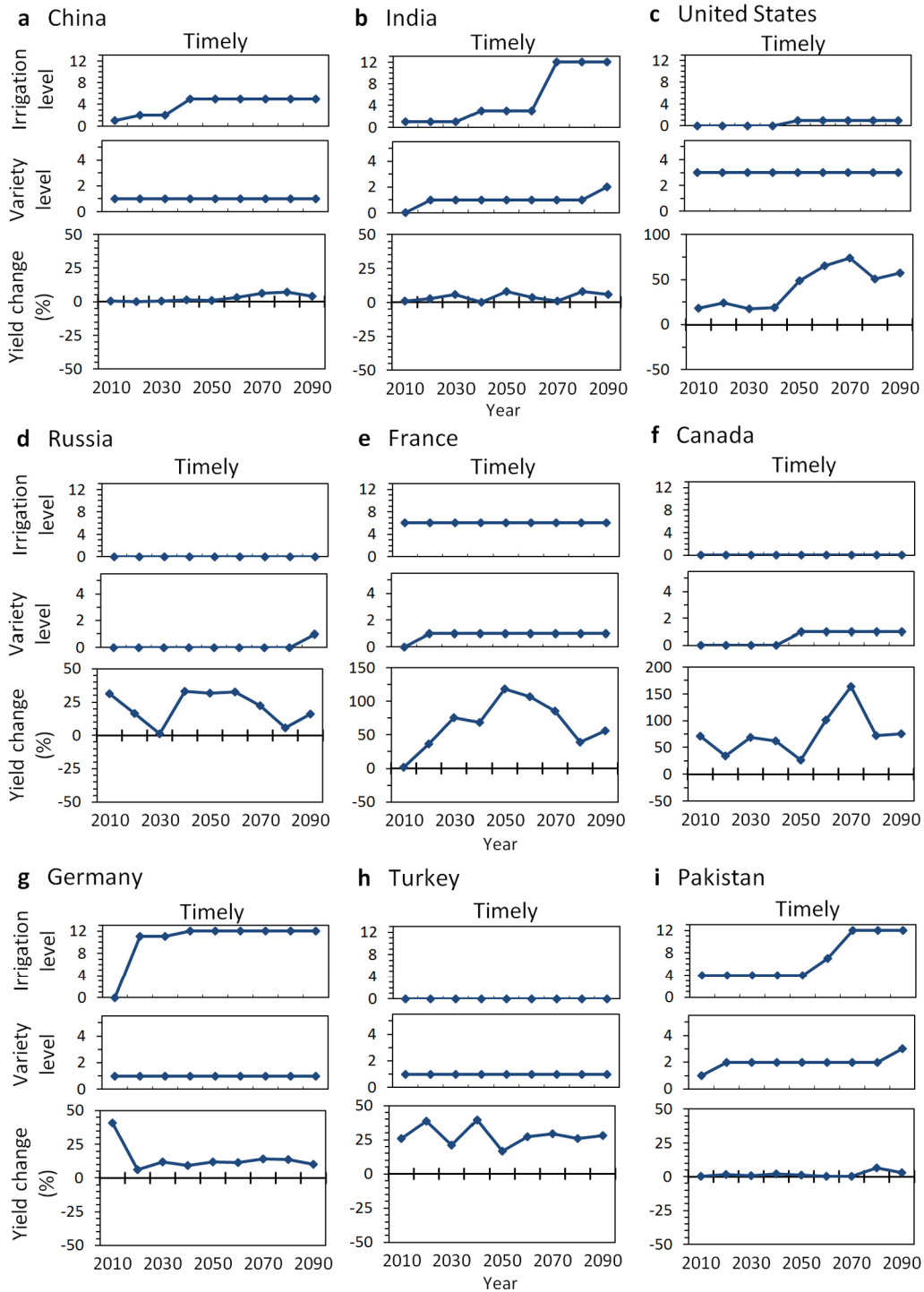
f Canada



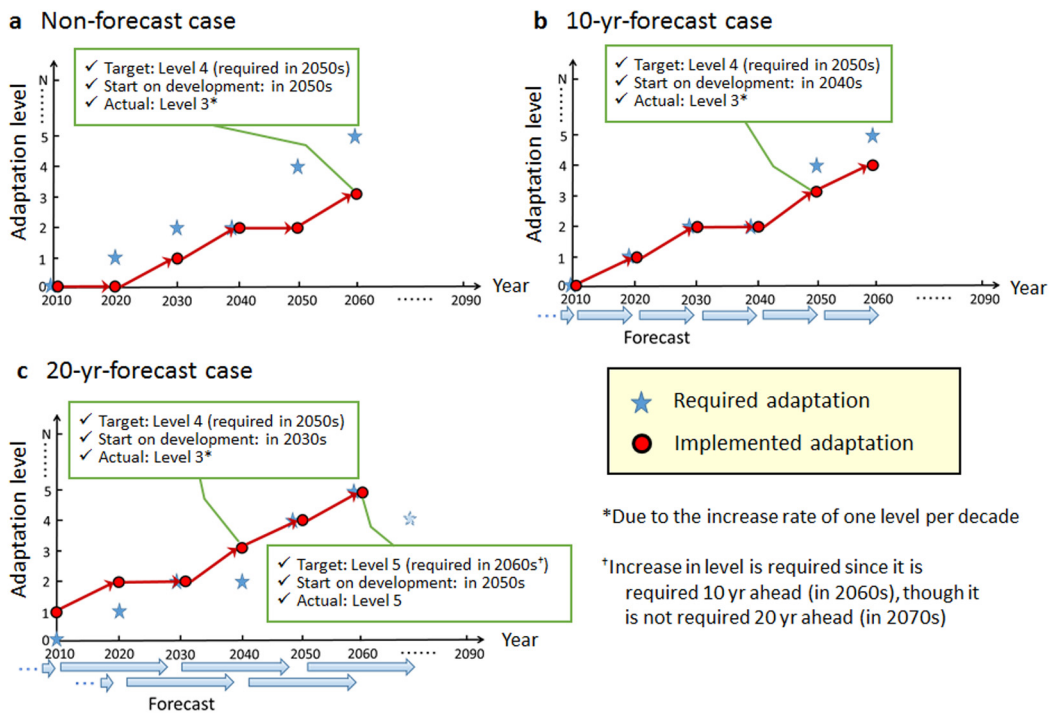
(Supplementary Figure S5; continued)



RCP2.6



Supplementary Figure S6 | Adaptation pathways and yield change from the current level in the timely case in the nine countries under the RCP2.6 scenario of the MIROC-ESM projection.



Supplementary Figure S7 | Conceptual diagram of the forecast cases (non-forecast case, 10-yr-forecast case, and 20-yr-forecast case).