RAW DATA FOR MODEL

Table S1 Hydroelectric Sites

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Site | Capacity (MW) | Energy (GWh/yr) | Capital (1997 $Mill) | Capital (2015 $Mill) |
| Mange 1 | 35.2 | 244.1 | 84.8 | 137 |
| Mange 2 | 12.8 | 108.6 | 51.8 | 83 |
| Tendata | 28.6 | 211.4 | 95.4 | 154 |
| Maka | 21 | 113.5 | 77.2 | 124 |
| \*Kuse 1 | 28 | 99.3 | 123.2 | 198 |
| Kuse 2 | 91.8 | 679.7 | 298 | 480 |
| Kumba | 48.9 | 302.8 | 166.7 | 268 |
| Kambatimbo | 65.7 | 322.1 | 81.2 | 131 |
| Rokon | 31.8 | 136.5 | 72 | 116 |
| Yiben | 61.5 | 442.9 | 90.6 | 146 |
| Yiben 2 | 62.1 | 430.2 | 122.4 | 197 |
| Komoia | 10.8 | 61.6 | 41.5 | 67 |
| Betmai 1 | 52.5 | 268.5 | 69 | 111 |
| Betmai 2 | 60 | 269.9 | 89.5 | 144 |
| Betmai 3 | 36.6 | 249.5 | 84.5 | 136 |
| Benkagor 1 | 34.8 | 237.2 | 102 | 164 |
| Benkagor 2 | 80 | 413.7 | 116.3 | 187 |
| Benkagor 3 | 85.5 | 513.1 | 77.4 | 125 |
| Titana | 22.2 | 95.9 | 52 | 84 |
| Levuma | 7.8 | 59 | 49.4 | 80 |
| Banda Karafain | 7.8 | 54.1 | 34.9 | 56 |
| Goma | 9.8 | 49.6 | 21 | 34 |
| Baraka | 39.6 | 233.8 | 87.5 | 141 |
| Nyandehu | 6.4 | 49.4 | 22.9 | 37 |
| Moyamba | 6.4 | 21.8 | 20.4 | 33 |
| \*Kabata Falls | 2.4 | 7.6 | 9 | 15 |
| \*\*Bumbuna | 26.8 | 205.8 | 75.8 | 123 |

\*Not Included in analysis

\*\* Already Developed

Data acquired from secondary source 1 because original report was not available.

Table S2 Population Centres in Sierra Leone

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number | District | Centre | Chiefdoms | Population |
| 1 | Western Urban | Freetown |  | 1055964 |
| 2 | Western Rural | Waterloo |  | 444270 |
| 3 | Port Loko | Masiaka | Koya, Masimera | 126020 |
| 4 |  | Lunsar | Marampa, Buya, Romende | 93604 |
| 5 |  | Port Loko | Maforki, Lokomasama | 165040 |
| 6 |  | Mange | Bureh Kasseh Makoateh, Sanda, Dibia, Tinkatupa | 11022 |
| 7 |  | Kasuan | Kaffu Bullom | 120490 |
| 8 | Kambia | Kambia | Magbema, Masungbala, Gbinle Dixing | 147395 |
| 9 |  | Rokupr | Mambolo, Samu | 102742 |
| 10 |  | Madina Junction | Tonko Limba, Bramaia | 95337 |
| 11 | Bombali | Makeni | Paki Masabong, Bombali Sebora, Makari Gbanti, Makeni | 263608 |
| 12 |  | Pendembu | Gbendembu Ngowahun, Sanda Tendaran, Gbanti Kamaranka, Libeisay | 109718 |
| 13 |  | Kamabai | Safroko, Limba, Biriwa, Magbaimba | 91249 |
| 14 |  | Kamakwie | Tambakha, Sella Limba, Samda Loko | 141969 |
| 15 | Koinadugu | Kabala | Diang, Sengbe, Wara, Wara Bafodia, Kasunko | 162626 |
| 16 |  | Falaba | Sulima, Dembelia-Sinkunia, Folosaba Dembelia | 78007 |
| 17 |  | Bendugu | Mongo, Neya, Nieni | 168739 |
| 18 | Tonkolili | Bumbuna | Kalansogoia, Samboya, Kafesiminia | 104527 |
| 19 |  | Masingbi | Kunke | 74415 |
| 20 |  | Magburaka | Kholifa Rowala, Khdifa Mabang, Malal Mara | 113747 |
| 21 |  | Matotaka | Gbonkolenken, Kunike Barina, Tane | 126235 |
| 22 |  | Yonibana | Yoni | 112511 |
| 23 | Kono | Yomadu | Kamara, Sandor | 109291 |
| 24 |  | Koidu | Tankaro, Gbane, Fiama, Gbense, Koidu Soa, Gbane Kandor, Mafindor, Lei, Toli | 289122 |
| 25 |  | Bumpe | Gorama Kono, Nimikoro, Nimiyama | 107687 |
| 26 | Kailahun | Bandajuma | Kpeje West, Yawei, Penguia | 83183 |
| 27 |  | Kailahun | Luawa | 81044 |
| 28 |  | Koindu | Kissi Teng, Kissi Kama, Kissi Tongi | 116520 |
| 29 |  | Pendembu | Malema, Mandu, Dea, Upper Bambara, Kpeje Bongre | 134510 |
| 30 |  | Daru | Jawie, Njalauhun | 113167 |
| 31 | Kenema | Boajibu | Simbaru, Wandor, Gorama Mende, Kandu Lepp | 99311 |
| 32 |  | Panguma | Malegohun, Lower Bambara, Dodo | 119683 |
| 33 |  | Kenema | Nongowa, Kenema, Small Bo, Niawa, Langrama | 286902 |
| 34 |  | Joru | Nomo, Tunkia, Gaura, Dama, Koya | 103995 |
| 35 | Pujehun | Zimmi | Soro Gbema, Makpele | 73372 |
| 36 |  | Potoru | Barri, Galliness Perri, Pejeh, Sowa | 122332 |
| 37 |  | Pujehun | Panga Krim, Panga Kabonde, Malen, Kpaka, Mono Sakrim, Yakemu Kpukumu | 150575 |
| 38 | Bonthe | Torma Bun | Kwamebai Krim, Bum | 82758 |
| 39 |  | Mattro Jung | Nongoba Bullom, Yawbeko, Soybeni, Kpanda Kemo, Jong | 38628 |
| 40 |  | Yagoi | Imperri, Sittia, Bendu-cha, Bonthe, Pema | 79395 |
| 41 | Bo | Koribondo | Wonde, Jaiama Bongor, Tikonko | 99809 |
| 42 |  | Sumbuya | Lugbu, Bagbo, Bumpe Nyao | 95616 |
| 43 |  | Bo | Bo, Kakua, Gbo | 230846 |
| 44 |  | Gerihun | Boama, Bagbwe, Badjia | 74896 |
| 45 |  | Dambara | Selenga, Niawa Lenga, Komboya, Valunia | 74311 |
| 46 | Moyamba | Taiama | Kori, Kamajei, Kowa, Dasse, Lower Bante, Upper Bante | 111478 |
| 47 |  | Moyamba | Fakunya, Ribbi, Bumpeh, Kongbora, Kaiyamba | 134333 |
| 48 |  | Sembehun | Bagruwa, Timdale, Kagboro | 72777 |

Table S3 Rice Production and Area of Centres

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Centre | % of Upland in District | % of Lowland in District | Mass Upland (kg) | Mass Lowland (kg) | Fraction Lowland of Total |
| 1 | Freetown | 0 | 0 | 0 | 0 | 0 |
| 2 | Waterloo | 100 | 100 | 759791 | 454688 | 0.37 |
|  | Port Loko |  |  | 30342719 | 27041723 | 0.47 |
| 3 | Masiaka | 30 | 30 | 9102816 | 8112517 | 0.47 |
| 4 | Lunsar | 30 | 0 | 9102816 | 0 | 0 |
| 5 | Port Loko | 0 | 30 | 0 | 8112517 | 1 |
| 6 | Mange | 40 | 20 | 12137088 | 5408347 | 0.31 |
| 7 | Kasuan | 0 | 20 | 0 | 5408345 | 1 |
|  | Kambia |  |  | 14072335 | 37062892 | 0.72 |
| 8 | Kambia | 40 | 40 | 5628934 | 14825157 | 0.72 |
| 9 | Rokupr | 0 | 40 | 0 | 14825157 | 1 |
| 10 | Madina Junction | 60 | 20 | 8443401 | 7412579 | 0.47 |
|  | Bombali |  |  | 23599052 | 15108202 | 0.39 |
| 11 | Makeni | 30 | 40 | 7079716 | 6043281 | 0.46 |
| 12 | Pendembu | 30 | 20 | 7079716 | 3021640 | 0.3 |
| 13 | Kamabai | 10 | 0 | 2359905 | 0 | 0 |
| 14 | Kamakwie | 30 | 40 | 7079716 | 6043281 | 0.46 |
|  | Koinadugu |  |  | 45339520 | 32024392 | 0.41 |
| 15 | Kabala | 40 | 40 | 18135808 | 12809757 | 0.41 |
| 16 | Falaba | 20 | 20 | 9067904 | 6404879 | 0.41 |
| 17 | Bendugu | 40 | 40 | 18135808 | 12809757 | 0.41 |
|  | Tonkoli |  |  | 31620809 | 13639466 | 0.3 |
| 18 | Bumbuna | 10 | 0 | 3162081 | 0 | 0 |
| 19 | Masingbi | 10 | 0 | 3162081 | 0 | 0 |
| 20 | Magburaka | 30 | 60 | 9486243 | 8183680 | 0.46 |
| 21 | Matotaka | 15 | 0 | 4743121 | 0 | 0 |
| 22 | Yonibana | 35 | 40 | 11067283 | 5455786 | 0.33 |
|  | Kono |  |  | 23613204 | 11110616 | 0.32 |
| 23 | Yomadu | 30 | 0 | 7083961 | 0 | 0 |
| 24 | Koidu | 35 | 50 | 8264621 | 5555308 | 0.4 |
| 25 | Bumpe | 35 | 50 | 8264621 | 5555308 | 0.4 |
|  | Kailahun |  |  | 35135813 | 13548122 | 0.28 |
| 26 | Bandajuma | 10 | 15 | 3513581 | 2032218 | 0.37 |
| 27 | Kailahun | 25 | 0 | 8783953 | 0 | 0 |
| 28 | Koindu | 0 | 0 | 0 | 0 | 0 |
| 29 | Pendembu | 25 | 15 | 8783953 | 2032218 | 0.19 |
| 30 | Daru | 40 | 70 | 14054325 | 9483685 | 0.4 |
|  | Kenema |  |  | 45726256 | 12253387 | 0.21 |
| 31 | Boajibu | 15 | 10 | 6858938 | 1225339 | 0.15 |
| 32 | Panguma | 25 | 10 | 11431564 | 1225338 | 0.1 |
| 33 | Kenema | 35 | 10 | 16004189 | 1225338 | 0.07 |
| 34 | Joru | 25 | 70 | 11431564 | 8577370 | 0.43 |
|  | Pujehun |  |  | 20946653 | 5859686 | 0.22 |
| 35 | Zimmi | 60 | 20 | 12567991 | 1171937 | 0.09 |
| 36 | Potoru | 40 | 20 | 8378661 | 1171937 | 0.12 |
| 37 | Pujehun | 0 | 60 | 0 | 3515811 | 1 |
|  | Bonthe |  |  | 2407423 | 3832821 | 0.61 |
| 38 | Torma Bun | 0 | 30 | 0 | 1149846 | 1 |
| 39 | Mattro Jung | 100 | 30 | 2407423 | 1149846 | 0.32 |
| 40 | Yagoi | 0 | 40 | 0 | 1533128 | 1 |
|  | Bo |  |  | 30135660 | 3387428 | 0.1 |
| 41 | Koribondo | 20 | 20 | 6027132 | 677485 | 0.1 |
| 42 | Sumbuya | 10 | 60 | 3013566 | 2032456 | 0.4 |
| 43 | Bo | 20 | 0 | 6027132 | 0 | 0 |
| 44 | Gerihun | 25 | 20 | 7533915 | 677485 | 0.08 |
| 45 | Dambara | 25 | 0 | 7533915 | 0 | 0 |
|  | Moyamba |  |  | 19077124 | 6002288 | 0.24 |
| 46 | Taiama | 50 | 40 | 9538562 | 2400915 | 0.2 |
| 47 | Moyamba | 50 | 30 | 9538562 | 1800686 | 0.16 |
| 48 | Sembehun | 0 | 30 | 0 | 1800686 | 1 |

Table S4 Total Rice Consumption 2-3

|  |  |  |  |
| --- | --- | --- | --- |
| Population | Production (tonne) | Import (tonne) | Consumption (kg/person) |
| 7100000 | 504292 | 310329 | 115 |

Table S5 Fertilizer Prices

Monoammonium phosphate (MAP)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Country | Tonnes |  |  | $1000 |  |  | $/tonne |  |  |
|  | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 |
| Ghana |  |  | 8340 |  |  | 1531 |  |  | 183 |
| Nigeria |  | 208 | 53 |  | 124 | 22 |  | 596 | 415 |
| Senegal | 404 | 775 | 633 | 417 | 367 | 464 | 1032 | 474 | 733 |
| Cameroon | 1775 | 1125 | 650 | 1153 | 724 | 323 | 650 | 643 | 497 |
|  |  |  |  |  |  |  |  | Average | 580 |

Potassium Chloride (KCl)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Country | Tonne |  |  | $1000 |  |  | $/t |  |  |
|  | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 |
| Ghana |  | 5833 | 7013 |  | 2039 | 2364 |  | 350 | 337 |
| Guinea |  | 81 | 7662 |  | 131 | 1480 |  | 383 | 193 |
| Nigeria |  | 5084 | 117619 |  | 1745 | 30892 |  | 343 | 263 |
| Senegal | 12042 | 12529 | 23876 | 4041 | 3253 | 5978 | 336 | 260 | 250 |
| Togo | 12700 | 550 | 19957 | 4967 | 158 | 5441 | 391 | 287 | 273 |
| Cameroon | 43525 | 29574 | 38210 | 15277 | 8613 | 11049 | 351 | 291 | 289 |
|  |  |  |  |  |  |  |  | Average | 310 |

Urea

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Country | Tonne |  |  | $1000 |  |  | $/t |  |  |
|  | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 |
| Ghana |  | 23248 | 88486 |  | 6643 | 25758 |  | 286 | 291 |
| Guinea | 354 | 1624 | 15190 | 120 | 531 | 3494 | 339 | 327 | 230 |
| Nigeria |  | 34265 |  |  | 11543 |  |  | 337 |  |
| Senegal | 42887 | 59803 | 81833 | 15863 | 17332 | 20057 | 370 | 290 | 245 |
| Togo |  | 9758 | 8590 |  | 2500 | 3618 |  | 256 | 421 |
| Benin |  | 15740 |  |  | 5880 |  |  | 374 |  |
| Cameroon | 52580 | 56761 | 74057 | 18298 | 15888 | 22140 | 348 | 280 | 299 |
|  |  |  |  |  |  |  |  | Average | 310 |

Table S6 Yields 4 Assuming a 32% loss in milling

|  |  |  |  |
| --- | --- | --- | --- |
| District | Mass Produced (t) | Area (ha) | Yield (t/ha) |
| Port Loko | 74638 | 97575 | 0.52 |
| Kambia | 65111 | 50369 | 0.88 |
| Bombali | 67538 | 78311 | 0.59 |
| Koinadugu | 46005 | 51011 | 0.61 |
| Tonkoli | 58317 | 75035 | 0.53 |
| Kono | 36761 | 38831 | 0.64 |
| Kailahun | 56481 | 58539 | 0.66 |
| Kenema | 51947 | 56685 | 0.62 |
| Pujehun | 28160 | 28795 | 0.665 |
| Bonthe | 19345 | 19616 | 0.67 |
| Bo | 35196 | 51464 | 0.465 |
| Moyamba | 42802 | 43836 | 0.66 |

Table S7 Coffee Cultivation 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Location | Mass Harvested (kg) | Area (ha) | Yield (mt/ha) |
| 49 | Kailahun | 12716952 | 66814 | 0.190 |
| 50 | Kenema | 5664474 | 34236 | 0.165 |
| 51 | Koidu | 3776394 | 61651 | 0.061 |

Table S8 Fertilizer Application for Rice 5

|  |  |  |  |
| --- | --- | --- | --- |
| Region | N kg/ha | P kg/ha | K kg/ha |
| Bangladesh | 80 | 12.2 | 14.1 |
| Haryana, India | 125 | 11.4 | 41.5 |
| Pattambi, India | 90 | 19.6 | 37.3 |
| Indonesia | 140 | 15.3 | 24.9 |
| Indonesia (dry) | 80 | 7.9 | 24.9 |
| West Java | 115 | 10.9 | 33.2 |
| Malaysia | 80 | 13.1 | 24.9 |
| Pakistan | 135 | 17.5 | 30.7 |
| Nueva Ecija, Philippines | 90 | 12.2 | 23.2 |
| Tarlac, Philippines | 80 | 21.8 | 24.9 |
| Sri Lanka | 73 | 25.3 | 48.1 |
| **Average** | 99 | 15 | 30 |

Table S10 | NPV for combinations of hydroelectric ammonia-urea plants

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | NPV wrt Rice ($Mill)[number of simulations] |  |
|  | Rice Only | With Coffee | Rice Irrigation and Coffe |
| One Site |  |  |  |
| Benkagor 3 | 1619 [150,000] | 1860 [200,000] | 2011 [250,000] |
| Two Sites |  |  |  |
| Benkagor 3+ Yiben 1 | 1735 [150,000] | 2074 [200,000] | 2207 [300,000] |
| Benkagor 3+ Yiben 2 | 1690 [100,000] | 1997 [200,000] | 2109 [250,000] |
| Three Sites |  |  |  |
| Benkagor 3+ Yiben 1+ Mange 1 | 1537 [100,000] | 2144 [300,00] | 2205 [500,000] |
| Benkagor 3+ Yiben 2+ Mange 1 | 1481 [100,000] | 2078 [250,000] | 2149 [500,000] |
| Benkagor 3+ Yiben 1+ Betmai 1 | 1518 [100,000] | 2173 [1,700,000] | 2197 [500,000] |
| Benkagor 3+ Yiben 2+ Betmai 1 | 1475 [100,000] | 2101 [250,000] | 2149 [500,000] |
| Benkagor 3+ Yiben 1+ Kambatimbo | NA | 2073 [100,000] | 2108 [500,000] |

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