Assessing the impacts of population growth and climate change on performance of water use systems in Kano River basin, Nigeria

Supplementary Material

Table 1 WaP quantities for M1P.

Quantity (Mm^3)	M1P0	M1P1	M1P2	M1P3
	2017, ref.	2025	2035	2050
VA_{KRIP}	206	206	216	247
ET_{KRIP}	86	86	91	104
RF_{KRIP}	101	101	106	116
RP_{KRIP}	32	32	34	37
OS_{KRIP1}	21	21	22	22

Table 2 Percentage change in WaP quantities for M1P.

% Change	M1P0	M1P1	M1P2	M1P3
	2017, ref.	2025	2035	2050
VA_{KRIP}	0	0	5	20
ET_{KRIP}	0	0	5	20
RF_{KRIP}	0	0	5	15
RP_{KRIP}	0	0	5	15
OS_{KRIP1}	0	0	5	5

Table 3 Beneficial weights for M1P.

Beneficial weights	M1P0	M1P1	M1P2	M1P3
	2017, ref.	2025	2035	2050
VA_{KRIP}	1	1	1	1
ET_{KRIP}	0.85	0.85	0.85	0.85
RF_{KRIP}	0.85	0.85	0.85	0.85
RP_{KRIP}	0.9	0.9	0.9	0.9
OS_{KRIP1}	1	1	1	1

Table 4 Quality weights for M1P.

Quality weights	M1P0	M1P1	M1P2	M1P3
	2017, ref.	2025	2035	2050
VA_{KRIP}	1	1	1	1
ET_{KRIP}	1	1	1	1
RF_{KRIP}	0.8	0.6	0.4	0.2
RP_{KRIP}	0.8	0.6	0.4	0.2
OS_{KRIP1}	1	1	1	1

Table 5 Reasons for the percentage changes in M1P.

	M1P1	**M1P2**	**M1P3**
VA_{KRIP}	population increase is relatively small and, according to our surveys, KRIP is getting more water than needed	moderate increase in population, more land is required for planting	high increase in population, much more land is required for planting
ET_{KRIP}	same VA, same ET	farm land increases	farm land increases
RF_{KRIP}	same VA, same RF	more applied water, more return flow	more applied water, more return flow
RP_{KRIP}	same VA, same RP under same soil conditions	more applied water, more groundwater recharge	more applied water, more groundwater recharge
OS_{KRIP1}	KRIP is already getting enough water	more land requires more water	more land requires more water

Table 6 WaP quantities for M2P.

Quantity Mm^3	M2P0 2017, ref.	M2P1 2025	M2P2 2035	M2P3 2050
VA	836	836	836	836
$OS_{IRCANAL}$	218	218	218	218
OS_{KM}	5	7	10	16
OS_{KRIP2}	246	246	258	283
OS_{RKR}	85	85	85	85
PP_{KR}	5	5	5	5
VU	836	836	836	836
ET	4	4	4	4
NR_{DAM}	214	214	214	214
NR_{KR}	62	62	62	62
NR_{RKR}	400	400	400	400
RF	411	365	305	197
RP_{DAM}	4	4	4	4
$RP_{IRCANAL}$	218	218	218	218
RP_{KCWS}	44	91	166	306
$RP_{SEEPAGE}$	39	39	39	39
VD	411	365	305	197

Table 7 Percentage change in WaP quantities for M2P.

% Change	M2P0 2017, ref.	M2P1 2025	M2P2 2035	M2P3 2050
VA	0	0	0	0
$OS_{IRCANAL}$	0	0	0	0
OS_{KM}	0	32	86	211
OS_{KRIP2}	0	0	5	15
OS_{RKR}	0	0	0	0
PP_{KR}	0	0	0	0
VU	0	0	0	0
ET	0	0	0	0
NR_{DAM}	0	0	0	0
NR_{KR}	0	0	0	0
NR_{RKR}	0	0	0	0
RF	0	-11	-26	-52
RP_{DAM}	0	0	0	0
$RP_{IRCANAL}$	0	0	0	0
RP_{KCWS}	0	106	276	592
$RP_{SEEPAGE}$	0	0	0	0
VD	0	-11	-26	-52

Table 8 Quality weights for M2P.

Quality weights	M2P0	M2P1	M2P2	M2P3
	2017, ref.	2025	2035	2050
VA	1	1	1	1
$OS_{IRCANAL}$	1	1	1	1
OS_{KM}	0.8	0.6	0.4	0.2
OS_{KRIP2}	0.8	0.6	0.4	0.2
OS_{RKR}	0.8	0.7	0.6	0.5
PP_{KR}	1	1	1	1
VU	1	1	1	1
ET	1	1	1	1
NR_{DAM}	1	1	1	1
NR_{KR}	1	1	1	1
NR_{RKR}	0.8	0.7	0.6	0.5
RF	0.8	0.6	0.4	0.2
RP_{DAM}	1	1	1	1
$RP_{IRCANAL}$	1	1	1	1
RP_{KCWS}	0.8	0.7	0.6	0.5
$RP_{SEEPAGE}$	0.8	0.6	0.4	0.2
VD	0.8	0.6	0.4	0.2

Table 9 Beneficial weights for M2P.

Beneficial weights	M2P0	M2P1	M2P2	M2P3
	2017, ref.	2025	2035	2050
VA	1	1	1	1
$OS_{IRCANAL}$	1	1	1	1
OS_{KM}	1	1	1	1
OS_{KRIP2}	1	1	1	1
OS_{RKR}	1	1	1	1
PP_{KR}	1	1	1	1
VU	1	1	1	1
ET	0.15	0.15	0.15	0.15
NR_{DAM}	0.3	0.3	0.3	0.3
NR_{KR}	0.3	0.3	0.3	0.3
NR_{RKR}	1	1	1	1
RF	1	1	1	1
RP_{DAM}	1	1	1	1
$RP_{IRCANAL}$	1	1	1	1
RP_{KCWS}	1	1	1	1
$RP_{SEEPAGE}$	1	1	1	1
VD	1	1	1	1

Table 10 Reasons for the percentage changes in M2P.

	M2P1	M2P2	M2P3
VA	abstracted water is not dependant on population change	abstracted water is not dependant on population change	abstracted water is not dependant on population change
$OS_{IRCANAL}$	same spills from small & bye-pass outlets	same spills from small & bye-pass outlets	same spills from small & bye-pass outlets
OS_{KM}	increase in population, more wastewater generation	increase in population, more wastewater generation	increase in population, more wastewater generation
OS_{KRIP2}	same return flow from KRIP	more water applied to KRIP due to increase in lands, more RF	more water applied to KRIP due to increase in lands, more RF
OS_{RKR}	same spills from RKR	same spills from RKR	same spills from RKR
PP_{KR}	same climatic conditions, same rainfall	same climatic conditions, same rainfall	same climatic conditions, same rainfall
VU	upstream flow is not dependant on population change	upstream flow is not dependant on population change	upstream flow is not dependant on population change
ET	same climatic conditions, same ET	same climatic conditions, same ET	same climatic conditions, same ET
NR_{DAM}	same climatic conditions, same evaporation from Tiga reservoir	same climatic conditions, same evaporation from Tiga reservoir	same climatic conditions, same evaporation from Tiga reservoir
NR_{KR}	same climatic conditions, same evaporation from Kano River	same climatic conditions, same evaporation from Kano River	same climatic conditions, same evaporation from Kano River
NR_{RKR}	enough water is applied to irrigation canal	enough water is applied to irrigation canal	enough water is applied to irrigation canal
RF	same as VD	same as VD	same as VD
RP_{DAM}	same volume upstream	same volume upstream	same volume upstream
$RP_{IRCANAL}$	same volume upstream	same volume upstream	same volume upstream
RP_{KCWS}	water supply coverage increases to achieve SDGs goal 6	moderate increase in population, more water required to achieve SDGs goal 6	high increase in population, much more water is required to achieve SDGs goal 6
$RP_{SEEPAGE}$	same RP under same soil conditions	same RP under same soil conditions	same RP under same soil conditions
VD	no regulation or policy that set the value of downstream flows	no regulation or policy that set the value of downstream flows	no regulation or policy that set the value of downstream flows

Table 11 WaP quantities for M1C.

Quantity Mm^3	M1C0 2017, ref.	M1C1 2025	M1C2 2035	M1C3 2050
VA_{KRIP}	206	216	216	216
ET_{KRIP}	86	87	89	91
RF_{KRIP}	101	106	106	106
RP_{KRIP}	32	34	34	34
OS_{KRIP}	21	21	21	21

Table 12 Percentage change in WaP quantities for M1C.

% Change	M1C0 2017, ref.	M1C1 2025	M1C2 2035	M1C3 2050
VA_{KRIP}	0	5	5	5
ET_{KRIP}	0	1.3	2.9	5.3
RF_{KRIP}	0	5	5	5
RP_{KRIP}	0	5	5	5
OS_{KRIP}	0	0	0	0

Table 13 Beneficial weights for M1C.

Beneficial weights	M1C0 2017, ref.	M1C1 2025	M1C2 2035	M1C3 2050
VA_{KRIP}	1	1	1	1
ET_{KRIP}	0.85	0.85	0.85	0.85
RF_{KRIP}	0.85	0.85	0.85	0.85
RP_{KRIP}	0.9	0.9	0.9	0.9
OS_{KRIP1}	1	1	1	1

Table 14 Quality weights for M1C.

Quality weights	M1C0 2017, ref.	M1C1 2025	M1C2 2035	M1C3 2050
VA_{KRIP}	1	1	1	1
ET_{KRIP}	1	1	1	1
RF_{KRIP}	0.8	0.6	0.4	0.2
RP_{KRIP}	0.8	0.6	0.4	0.2
OS_{KRIP1}	1	1	1	1

Table 15 Reasons for the percentage changes in M1C.

	M1C1	**M1C2**	**M1C3**
VA_{KRIP}	more irrigation water requirements	more irrigation water requirements	more irrigation water requirements
ET_{KRIP}	temperature increases	temperature increases	temperature increases
RF_{KRIP}	more applied water, more return flow	more applied water, more return flow	more applied water, more return flow
RP_{KRIP}	more applied water, more groundwater recharge	more applied water, more groundwater recharge	more applied water, more groundwater recharge
OS_{KRIP1}	KRIP is already getting enough water	KRIP is already getting enough water	KRIP is already getting enough water

Table 16 WaP quantities of M2C.

Quantity	M2C0	M2C1	M2C2	M2C3
Mm^3	2017, ref.	2025	2035	2050
VA	836	794	773	752
$OS_{IRCANAL}$	218	214	209	203
OS_{KM}	5	5	5	5
OS_{KRIP2}	246	258	258	258
OS_{RKR}	85	83	82	79
PP_{KR}	5	5	5	5
VU	836	794	773	752
ET	4	4	4	4
NR_{DAM}	214	219	225	234
NR_{KR}	62	63	65	68
NR_{RKR}	400	392	384	372
RF	411	382	361	339
RP_{DAM}	4	4	4	4
$RP_{IRCANAL}$	218	214	209	203
RP_{KCWS}	44	44	44	44
$RP_{SEEPAGE}$	39	38	37	36
VD	411	382	361	339

Table 17 Percentage change in WaP quantities for M2.

% Change	M2C0	M2C1	M2C2	M2C3
	2017, ref.	2025	2035	2050
VA	0	-5	-7.5	-10
$OS_{IRCANAL}$	0	-2	-4	-7
OS_{KM}	0	0	0	0
OS_{KRIP2}	0	5	5	5
OS_{RKR}	0	-2	-4	-7
PP_{KR}	0	0.8	1.1	1.4
VU	0	-5	-7.5	-10
ET	0	1.3	2.9	5.3
NR_{DAM}	0	2.2	5.0	9.2
NR_{KR}	0	2.2	5.0	9.2
NR_{RKR}	0	-2	-4	-7
RF	0	-7	-12	-18
RP_{DAM}	0	-2	-4	-7
$RP_{IRCANAL}$	0	-2	-4	-7
RP_{KCWS}	0	0	0	0
$RP_{SEEPAGE}$	0	-2	-4	-7
VD	0	-7	-12	-18

Table 18 Quality weights for M2C.

Quality weights	M2C0	M2C1	M2C2	M2C3
	2017, ref.	2025	2035	2050
VA	1	0.9	0.8	0.7
$OS_{IRCANAL}$	1	0.9	0.8	0.7
OS_{KM}	1	0.9	0.8	0.7
OS_{KRIP2}	0.8	0.7	0.6	0.5
OS_{RKR}	1	0.9	0.8	0.7
PP_{KR}	1	1	1	1
VU	1	0.9	0.8	0.7
ET	1	1	1	1
NR_{DAM}	1	1	1	1
NR_{KR}	1	1	1	1
NR_{RKR}	1	0.9	0.8	0.7
RF	0.8	0.6	0.4	0.2
RP_{DAM}	1	0.9	0.8	0.7
$RP_{IRCANAL}$	1	0.9	0.8	0.7
RP_{KCWS}	1	0.9	0.8	0.7
$RP_{SEEPAGE}$	0.8	0.6	0.4	0.2
VD	0.8	0.6	0.4	0.2

Table 19 Beneficial weights for M2C.

Beneficial weights	M2P0	M2P1	M2P2	M2P3
	2017, ref.	2025	2035	2050
VA	1	1	1	1
$OS_{IRCANAL}$	1	1	1	1
OS_{KM}	1	1	1	1
OS_{KRIP2}	1	1	1	1
OS_{RKR}	1	1	1	1
PP_{KR}	1	1	1	1
VU	1	1	1	1
ET	0.15	0.15	0.15	0.15
NR_{DAM}	0.3	0.3	0.3	0.3
NR_{KR}	0.3	0.3	0.3	0.3
NR_{RKR}	1	1	1	1
RF	1	1	1	1
RP_{DAM}	1	1	1	1
$RP_{IRCANAL}$	1	1	1	1
RP_{KCWS}	1	1	1	1
$RP_{SEEPAGE}$	1	1	1	1
VD	1	1	1	1

Table 20 Reasons for the percentage changes in M2C.

	M2C1	M2C2	M2C3
VA	VU decreases	VU decreases	VU decreases
$OS_{IRCANAL}$	less water to irrigation canal, less spills from small & bye-pass outlets	less water to irrigation canal, less spills from small & bye-pass outlets	less water to irrigation canal, less spills from small & bye-pass outlets
OS_{KM}	influence of global warming on wastewater generation is negligible	influence of global warming on wastewater generation is negligible	influence of global warming on wastewater generation is negligible
OS_{KRIP2}	more applied water, more return flow from KRIP	more applied water, more return flow from KRIP	more applied water, more return flow from KRIP
OS_{RKR}	less water to RKR, less spills from RKR	less water to RKR, less spills from RKR	less water to RKR, less spills from RKR
PP_{KR}	rainfall increases	rainfall increases	rainfall increases
VU	more evaporation due to temperature increase	more evaporation due to temperature increase	more evaporation due to temperature increase
ET	temperature increases	temperature increases	temperature increases
NR_{DAM}	temperature increases	temperature increases	temperature increases
NR_{KR}	temperature increases	temperature increases	temperature increases
NR_{RKR}	water upstream decreases	water upstream decreases	water upstream decreases
RF	VA decreases	VA decreases	VA decreases
RP_{DAM}	water upstream decreases	water upstream decreases	water upstream decreases
$RP_{IRCANAL}$	water upstream decreases	water upstream decreases	water upstream decreases
RP_{KCWS}	influence of global warming on water use is negligible	influence of global warming on water use is negligible	influence of global warming on water use is negligible
$RP_{SEEPAGE}$	less water in Kano River, less groundwater recharge under same soil conditions	less water in Kano River, less groundwater recharge under same soil conditions	less water in Kano River, less groundwater recharge under same soil conditions
VD	no regulation or policy that set the value of downstream flows	no regulation or policy that set the value of downstream flows	no regulation or policy that set the value of downstream flows

Table 21 WaP quantities for M1B.

Quantity Mm^3	M1B0 2017, ref.	M1B1 2025	M1B2 2035	M1B3 2050
VA_{KRIP}	206	216	226	257
ET_{KRIP}	86	87	93	108
RF_{KRIP}	101	106	111	121
RP_{KRIP}	32	34	36	39
OS_{KRIP}	21	21	22	22

Table 22 Percentage change in WaP quantities for M1B.

% Change	M1B0 2017, ref.	M1B1 2025	M1B2 2035	M1B3 2050
VA_{KRIP}	0	5	10	25
ET_{KRIP}	0	1.3	7.9	25.3
RF_{KRIP}	0	5	10	20
RP_{KRIP}	0	5	10	20
OS_{KRIP}	0	0	5	5

Table 23 Quality weights for M1B.

Quality weights	M1B0 2017, ref.	M1B1 2025	M1B2 2035	M1B3 2050
VA_{KRIP}	1	1	1	1
ET_{KRIP}	1	1	1	1
RF_{KRIP}	0.8	0.6	0.5	0.3
RP_{KRIP}	0.8	0.6	0.5	0.3
OS_{KRIP1}	1	1	1	1

Table 24 Beneficial weights for M1B.

Beneficial weights	M1B0 2017, ref.	M1B1 2025	M1B2 2035	M1B3 2050
VA_{KRIP}	1	1	1	1
ET_{KRIP}	0.85	0.85	0.85	0.85
RF_{KRIP}	0.85	0.85	0.85	0.85
RP_{KRIP}	0.9	0.9	0.9	0.9
OS_{KRIP1}	1	1	1	1

Table 25 WaP quantities for M2B.

Quantity Mm^3	M2B0 2017, ref.	M2B1 2025	M2B2 2035	M2B3 2050
VA	836	794	773	752
$OS_{IRCANAL}$	218	214	209	203
OS_{KM}	5	7	10	16
OS_{KRIP2}	246	258	271	295
OS_{RKR}	85	83	82	79
PP_{KR}	5	5	5	5
VU	836	794	773	752
ET	4	4	4	4
NR_{DAM}	214	219	225	234
NR_{KR}	62	63	65	68

NR_{RKR}	400	392	384	372
RF	411	337	255	125
RP_{DAM}	4	4	4	4
$RP_{IRCANAL}$	218	214	209	203
RP_{KCWS}	44	91	166	306
$RP_{SEEPAGE}$	39	38	37	36
VD	411	337	255	125

Table 26 Percentage change in WaP quantities for M2B.

% Change	M2B0	M2B1	M2B2	M2B3
	2017, ref.	2025	2035	2050
VA	0	-5	-7.5	-10
$OS_{IRCANAL}$	0	-2	-4	-7
OS_{KM}	0	32	86	211
OS_{KRIP2}	0	5	10	20
OS_{RKR}	0	-2	-4	-7
PP_{KR}	0	0.8	1.1	1.4
VU	0	-5	-7.5	-10
ET	0	1.3	2.9	5.3
NR_{DAM}	0	2.2	5.0	9.2
NR_{KR}	0	2.2	5.0	9.2
NR_{RKR}	0	-2	-4	-7
RF	0	-18	-38	-70
RP_{DAM}	0	-2	-4	-7
$RP_{IRCANAL}$	0	-2	-4	-7
RP_{KCWS}	0	106	276	592
$RP_{SEEPAGE}$	0	-2	-4	-7
VD	0	-18	-38	-70

Table 27 Quality weights for M2B.

Quality weights	M2B0	M2B1	M2B2	M2B3
	2017, ref.	2025	2035	2050
VA	1	0.95	0.9	0.85
$OS_{IRCANAL}$	1	0.95	0.9	0.85
OS_{KM}	0.9	0.75	0.6	0.45
OS_{KRIP2}	0.8	0.65	0.5	0.35
OS_{RKR}	0.9	0.8	0.7	0.6
PP_{KR}	1	1	1	1
VU	1	0.95	0.9	0.85
ET	1	1	1	1
NR_{DAM}	1	1	1	1
NR_{KR}	1	1	1	1
NR_{RKR}	0.9	0.8	0.7	0.6
RF	0.8	0.6	0.4	0.2
RP_{DAM}	1	0.95	0.9	0.85
$RP_{IRCANAL}$	1	0.95	0.9	0.85
RP_{KCWS}	0.9	0.8	0.7	0.6
$RP_{SEEPAGE}$	0.8	0.6	0.4	0.2
VD	0.8	0.6	0.4	0.2

Table 28 Beneficial weights for M2B.

Beneficial weights	M2B0	M2B1	M2B2	M2B3
	2017, ref.	2025	2035	2050
VA	1	1	1	1
$OS_{IRCANAL}$	1	1	1	1
OS_{KM}	1	1	1	1
OS_{KRIP2}	1	1	1	1
OS_{RKR}	1	1	1	1
PP_{KR}	1	1	1	1
VU	1	1	1	1
ET	0.15	0.15	0.15	0.15
NR_{DAM}	0.3	0.3	0.3	0.3
NR_{KR}	0.3	0.3	0.3	0.3
NR_{RKR}	1	1	1	1
RF	1	1	1	1
RP_{DAM}	1	1	1	1
$RP_{IRCANAL}$	1	1	1	1
RP_{KCWS}	1	1	1	1
$RP_{SEEPAGE}$	1	1	1	1
VD	1	1	1	1