Screening Woody Species for Afforestation of Degraded Croplands in the Sudano-Sahelian Zone of Benin

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Background

- Deforestation and cropland/soil degradation in Sub-Saharan Africa increase pressure on marginal lands, poorly suitable for agriculture, thus advancing environmental degradation and lowering agroecosystem productivity
- Afforestation/reforestation with well-adapted multi-purpose trees can reverse land degradation and sustain farming systems in drylands such as in Northern Benin (Figures 1 and 3)
- Understanding the process of tree establishment and early growth on degraded cropland is a prerequisite for a successful selection of woody species and afforestation/reforestation planning

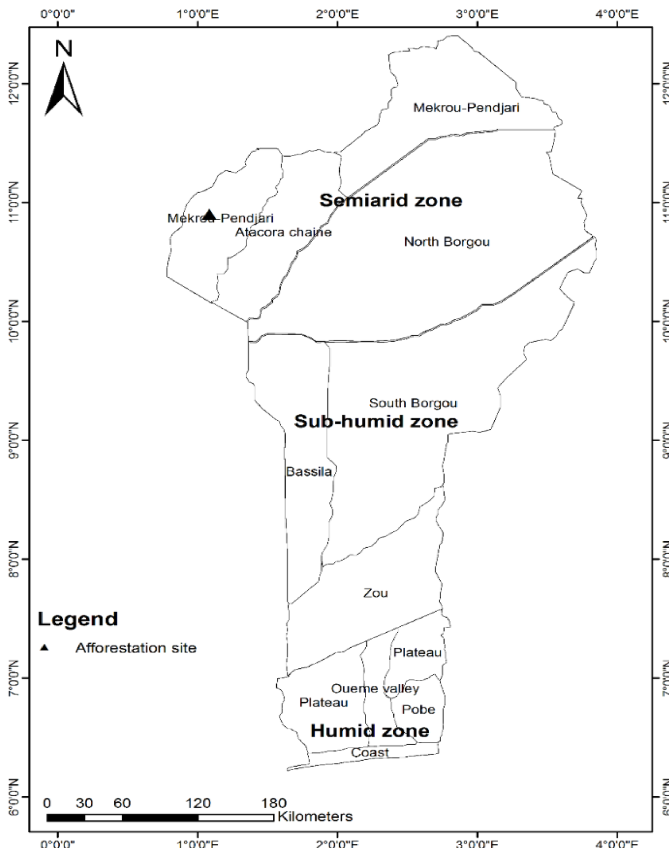

Figure 1. Map of the study area indicating the afforestation site

Objectives

- To assess the establishment and growth responses to manuring and supplemental irrigation of five woody species on degraded cropland during the first 15 months after planting (MaP)

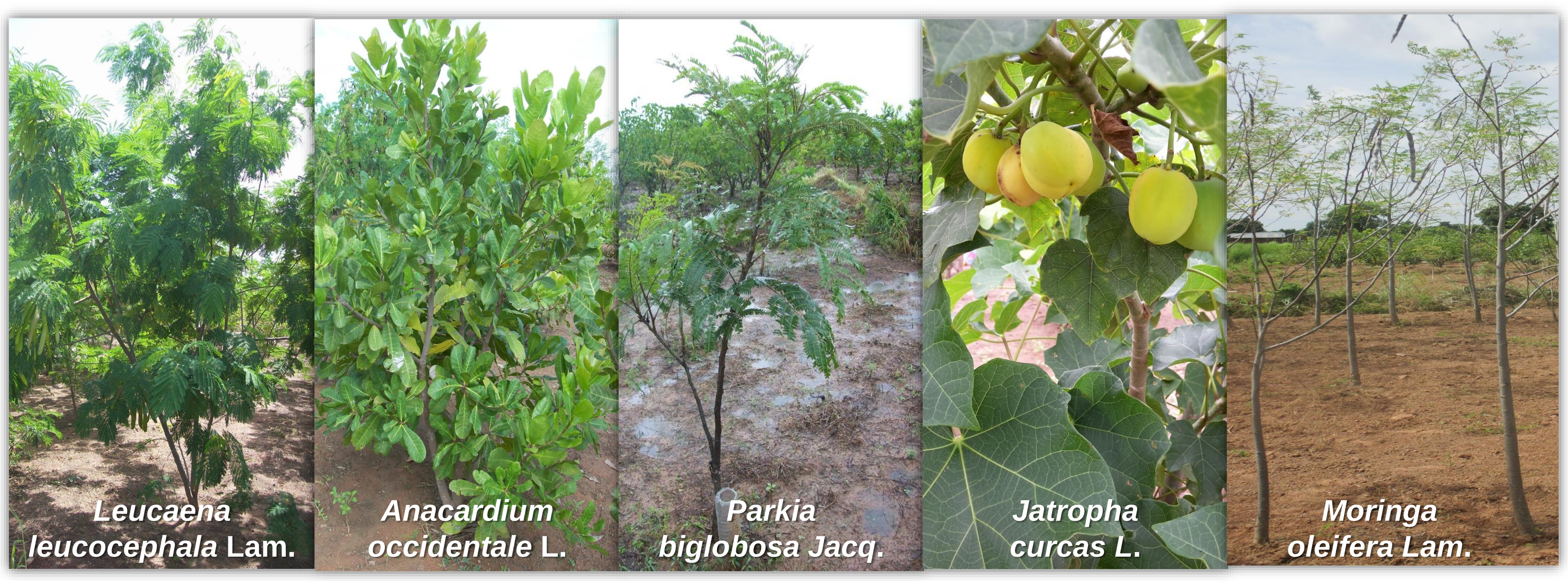

Figure 2. Five woody species used in the afforestation trial in Northern Benin

Materials and methods

- Afforestation trial was installed in July 2014 on a degraded cropland (low concentrations of CNPK, Figure 3) in Pouri village of Atacora, semi-arid zone of Benin (Figures 1 & 4) and included 5 species (Figure 2)
- Silvicultural treatments consisted of manuring and drip irrigation with 2 levels each (no application and application). Timing of treatment application and plant traits evaluation are indicated in Figure 4. Data were collected on shoot- and root-level morphological traits (Table)

Figure 3. Bare and degraded cropland before tree planting in Northern Benin (July 2014)

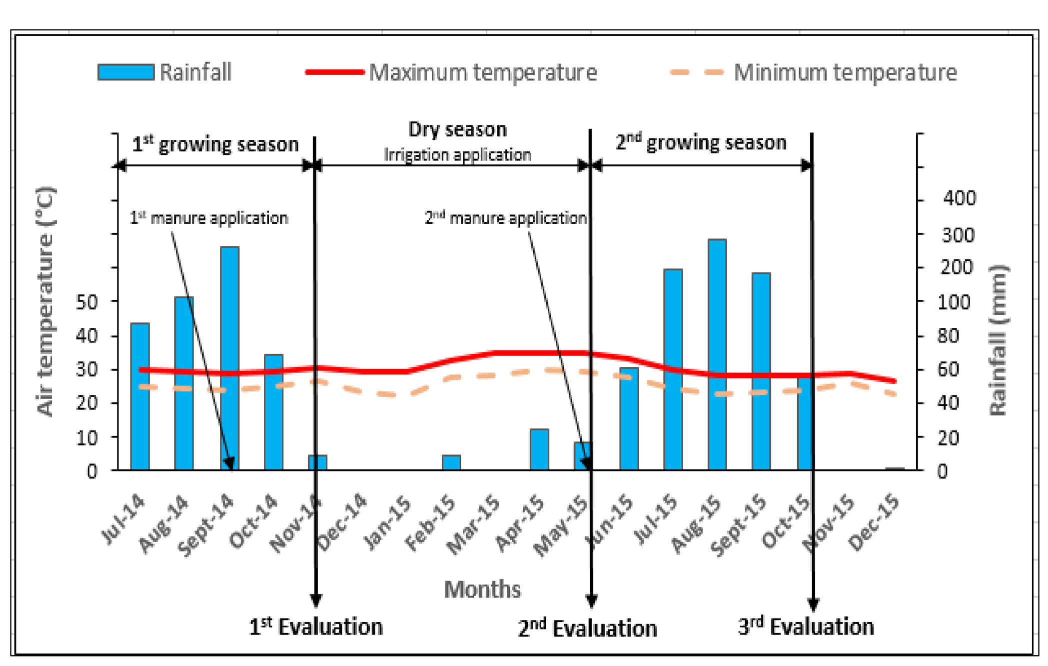

Figure 4. Ambient temperature and seasonal rainfall during the study period as well as timing of manure and irrigation applications and plant trait evaluation

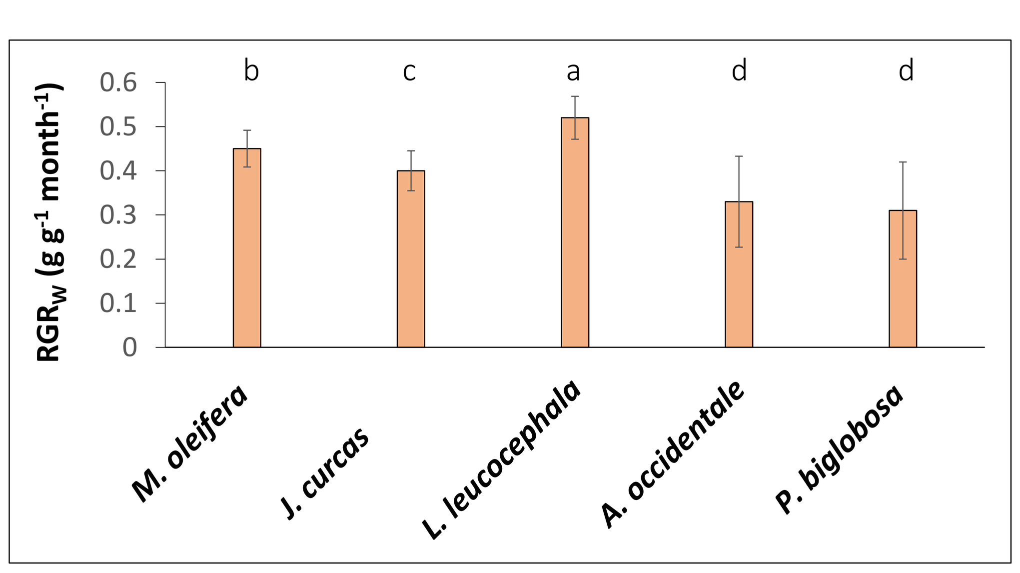

Figure 5. Relative growth rates of the whole-plant biomass (RGR_W) of 5 species for the period between the initial (MaP=0) and the last harvest (15 MaP) across treatments. Bars are standard errors of the means. Different letters indicate significant differences between species at $p < 0.05$ according to the LSD post hoc test.

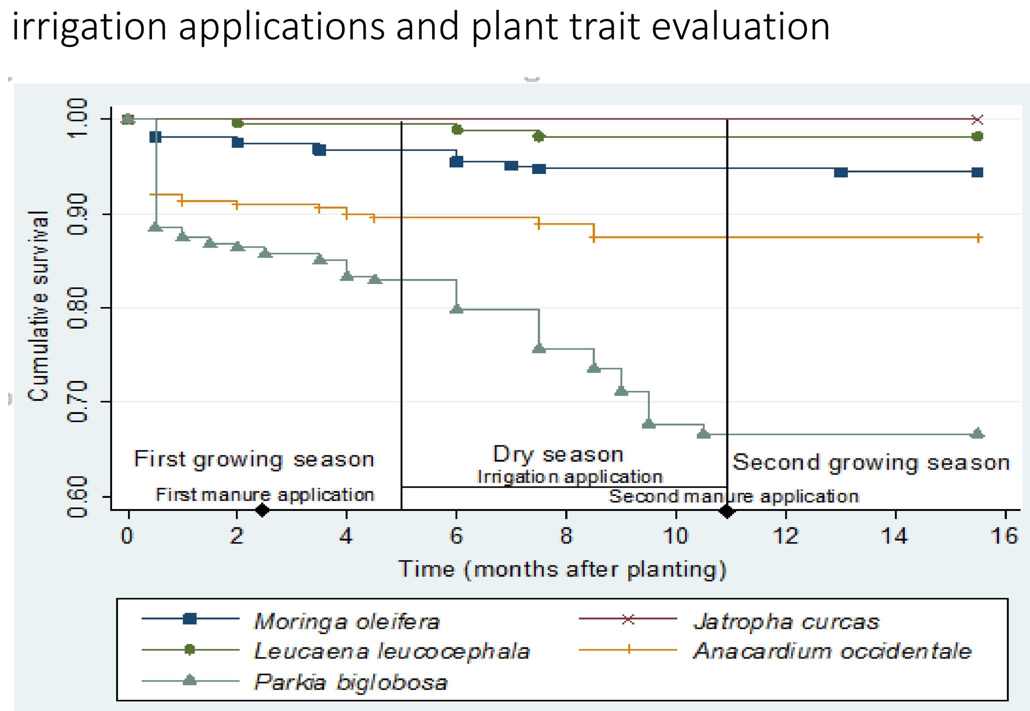

Figure 6. Species survival during the first 15 months after planting (MaP)

Key findings

- Overall high survival rates (>60%) with a very low incidence rate (<0.01%) evidenced the successful establishment of all species, but particularly of *J. curcas*, *L. leucocephala* and *M. oleifera* which had the highest rates (67-100%) (Figure 6)
- Supply of water during the dry season significantly reduced the mortality rate (10 fold) of the most drought-sensitive species *P. biglobosa*
- Significantly higher relative growth rates (RGR_W) were recorded for *L. leucocephala*, *M. oleifera* and *J. curcas* than for *A. occidentale* and *P. biglobosa* (Figure 5)
- Both fast-growers (*L. leucocephala*, *M. oleifera* and *J. curcas*) and slow-growers (*A. occidentale* and *P. biglobosa*) responded to fertilization and irrigation by enhancing the shoot growth during both growing seasons (Table)
- Only slow-growers significantly increased the shoot-level traits (D and RGR_D) in response to fertilization during the dry season (Table)
- Treatments caused changes (increase or reduction) in root elongation (RE & RGR_{RE}) observed in both fast- and slow-growers, but the two slow-growers showed more plastic response than the fast-growers (Table)

Table. Relative changes (in %) induced by fertilization (F) and irrigation (I) in shoot-and root-level traits of five woody species at T_1 (1st growing season), T_2 (dry season) and T_3 (2nd growing season). Changes were calculated based on the mean values of each treatment factor (no application vs application) from a linear mixed-effects model. Bold values with (*) indicate significant changes according to the LSD post-hoc test on mean values

Shoot-level traits

Species	Factors	Basal diameter (D)			Height (H)			Relative growth rate in D (RGR_D)			Relative growth rate in H (RGR_H)		
		T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
MO	F	**+6***	-1	+18	+7	-3	+8	+1	0	+5	+2	0	+2
	I	-	+3	0	-	-3	+1	-	0	0	-	0	0
JC	F	**+9***	+1	+9	+3	+3	+8	+3	0	+3	0	+0	**+2***
	I	-	-1	**+7***	-	15	-3	-	0	**+2***	-	+1	-1
LL	F	**+13***	-1	+15	+8	+9	+5	+3	-1	+4	+2	+1	**+2***
	I	-	-17	-19	-	-15	-6	-	-1	-5	-	-1	-2
AO	F	+1	+8	+13	+3	+3	**+13***	0	**+1***	+3	+1	0	**+3***
	I	-	+9	+16	-	+12	+21	-	+2	+3	-	+1	+4
PB	F	**+30***	**+35***	+3	+17	+18	+18	+5	**+5***	+4	+3	+3	**+5***
	I	-	-10	+24	-	+7	**+30***	-	0	**+5***	-	+1	**+6***

Root-level traits

Species	Factors	Rooting depth (RD)			Maximum extent of lateral roots (RE)			Relative growth rate in RD (RGR_{RD})			Relative growth rate in RE (RGR_{RE})		
		T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
MO	F	-6	-6	-4	+8	**-28***	-2	0	-1	0	0	-3	0
	I	-	-11	-2	-	+2	**+9***	-	0	0	-	0	+2
JC	F	+7	+13	+9	-3	-3	-5	+2	+2	+1	-1	0	-1
	I	-	0	+2	-	-6	-4	-	0	+2	-	-1	-1
LL	F	+2	+13	-12	+9	-3	-7	+1	+2	-1	+2	0	0
	I	-	-28	+1	-	-1	**-13***	-	-1	-5	-	0	-1
AO	F	+3	+17	+4	**-26***	+10	-3	0	+2	0	**-7***	1	-1
	I	-	-8	+6	-	+8	**+15***	-	+1	+3	-	0	+4
PB	F	-2	+7	-2	**+27***	**-35***	-21	-1	0	0	+4	-4	-6
	I	-	-9	+11	-	-15	**+12***	-	0	+5	-	-2	+2

MO= *M. oleifera*, JC= *J. curcas*, LL= *L. leucocephala*, AO= *A. occidentale*, PB= *P. biglobosa*. Manure was applied during the first and second rainy seasons. Irrigation was applied during the dry season.

Implications for afforestation

- Fast growing species showed the highest potential for planting on degraded cropland, as reflected in responsiveness of aboveground traits to silvicultural management
- Slow-growers depicted more abilities to grow under low-resource conditions and adjust to stress factors
- The mixed cultivation of fast- and slow-growers could help diversify the risks and potential benefits from afforestation

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